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Engineering Safety-Related Requirements for Software-Intensive Systems

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The Challenge

- Poor requirements are a root cause of many (or most) accidents involving software-intensive systems.
- Requirements engineering and safety engineering:
  - Different *communities*
  - Different *disciplines* with different training, books, journals, and conferences
  - Different *professions* with different job titles
  - Different fundamental underlying *concepts* and terminologies
  - Different *tasks, techniques,* and *tools*
- This separation of RE and SE causes poor safety-related requirements.

Topics

- Requirements Engineering Overview for Safety Team
- Safety Engineering Overview for Requirements Team
- Break (3:00PM – 3:30PM)
- Safety-Related Requirements:
  - Safety [Quality] Requirements
  - Safety-Significant Requirements
  - Safety Subsystem Requirements
  - Safety Constraints
- Method for Engineering Safety-Related Requirements

Requirements Engineering Overview

- Definition of Requirements Engineering
- Importance and Difficulty of Requirements Engineering
- Goals vs. Scenarios vs. Requirements
- Characteristics of Good Requirements
- Types of Requirements

Requirements Engineering

- **Requirements engineering** (RE) is the cohesive collection of all *tasks* that are primarily performed to produce the *requirements* and *other related requirements work products* for an *endeavor*.

- Today, these RE tasks are typically performed in an *iterative*, *incremental*, *parallel,* and *ongoing* manner rather than according to the traditional Waterfall development cycle.

Importance of Requirements

- Poor requirements are a primary cause of more than half of all project failures (defined in terms of):
  - Major cost overruns
  - Major schedule overruns
  - Major functionality not delivered
  - Cancelled projects
  - Delivered systems that are never used

Difficulty of Requirements

- “The hardest single part of building a software system is deciding precisely what to build. No other part of the conceptual work is as difficult as establishing the detailed technical requirements, including all the interfaces to people, to machines, and to other software systems. No other part of the work so cripples the resulting system if done wrong. No other part is more difficult to rectify later.”

  F. Brooks, *No Silver Bullet*, IEEE Computer, 1987

Goals

- A **goal** is an *informally documented perceived need* of a *legitimate stakeholder*.
  - Goals are typically documented in a vision statement.
  - Goals drive the analysis and formal specification of the requirements.
  - Examples:
    - The system shall support user activity X.
    - The system shall be efficient.
    - The system shall be easy to use.
    - The system shall be safe to use.
  - Goals are typically not verifiable.
  - Goals may not be feasible.

Usage Scenarios

- A **usage scenario** is a specific functionally cohesive sequence of interactions between user(s), the system, and potentially other actors that provides value to a stakeholder.
- Usage scenarios:
  - Are instances of use cases.
  - Can be either “sunny day” or “rainy day” scenarios.
  - Have preconditions, triggers, and postconditions.
  - Are typically documented in an Operational Concept Document (OCD).
  - Drive the analysis and formal specification of the [primarily functional] requirements.
  - Often include potential design information.
  - Can be written in either list or paragraph form.

Requirements

- A (product) **requirement** is a *mandatory* characteristic (behavior or attribute) of a product (e.g., system, subsystem, software application, or component).
  - Requirements are documented in requirements specifications.
  - Requirements are driven by goals.
  - Requirements are analyzed using scenarios.
  - Requirements must have certain characteristics (e.g., verifiable and feasible).

Characteristics of Good Requirements

- **Mandatory**
- **Correct**
- **Cohesive**
- **Feasible**
- **Relevant**
- **Unique**
- **Unambiguous**
- **Validatable**
- **Verifiable**
- **What or How Well, not How**

- Complete
- Consistent
- Usable by Stakeholders
- Uniquely Identified
- Traced
- Externally Observable
- Stakeholder-Centric
- Properly Specified
- Prioritized
- Scheduled
- Managed
- Controlled

http://www.jot.fm/issues/issue_2003_07/column7

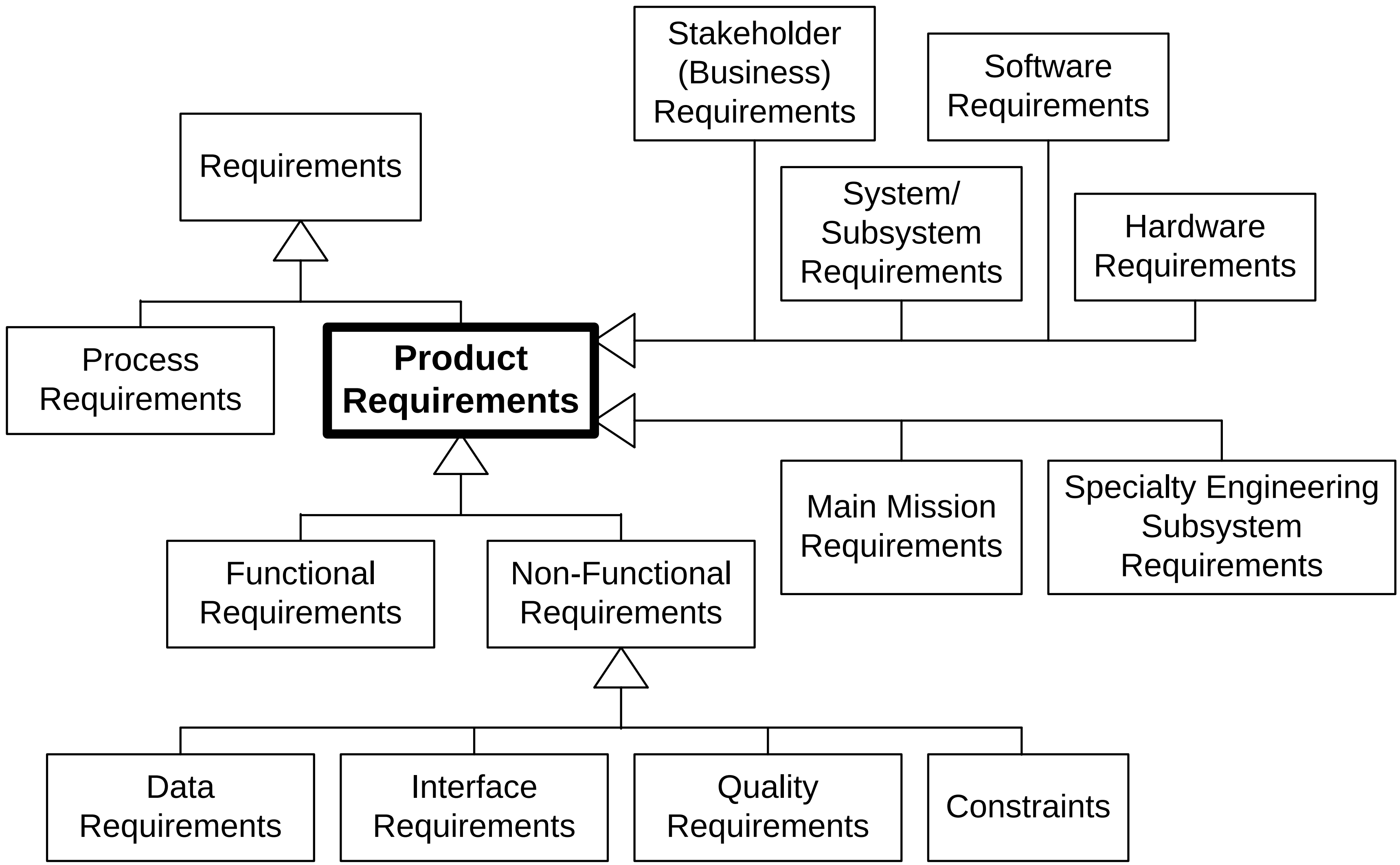
Some Problems due to Poor Requirements

- Ambiguous Requirements:
  - Developers misinterpret Subject Matter Expert (SME) intentions.
  - “The system shall be safe.”
  - How safe? Safe in what way?
- Incomplete Requirements:
  - Developers must guess SME intentions.
  - The system shall do X.”
  - Under what conditions? When in what state? When triggered by what event? How often? How fast? For whom? With what result?

More Problems

- Missing Requirements:
  - What shall the system do if it can’t do X?
  - Unusual combinations of conditions often result in accidents.
  - What shall the system do if event X occurs when the system is simultaneously in states Y and Z?
- Unnecessary Constraints:
  - Inappropriate architecture and design constraints unnecessarily specified as requirements such as:
    - User ID and password for identification and authentication.

Types of Requirements



Product Requirements

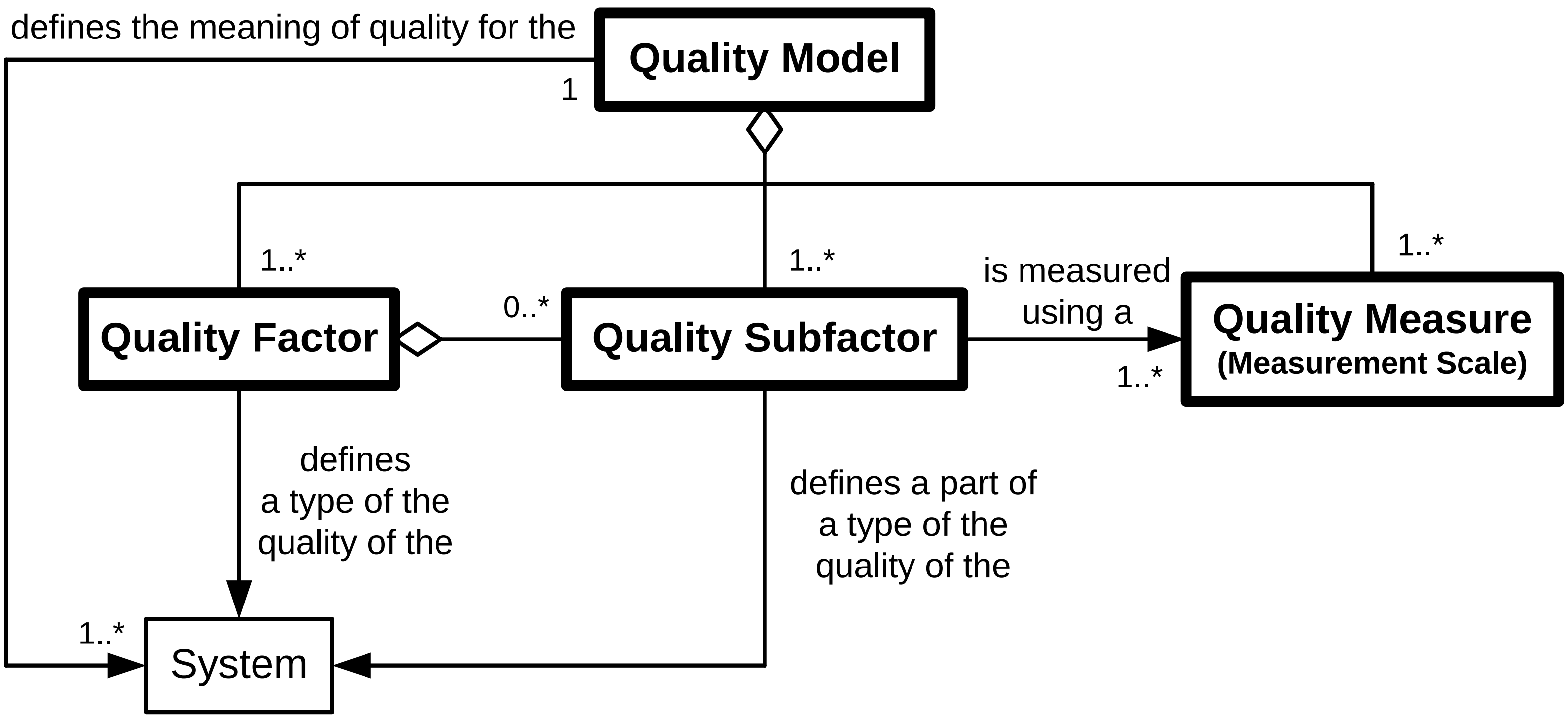
- A **product requirement** is a requirement for a *product* (e.g., system, subsystem, software application, or component).
  - A **functional requirement** is a product requirement than specifies a mandatory *function* (i.e., behavior) of the product.
  - A **data requirement** is a product requirement that specifies mandatory [types of] data that must be manipulated by the product.
  - An **interface requirement** is a product requirement that specifies a mandatory interface with (or within) the product.
  - A **quality requirement** is a product requirement that specifies a mandatory amount of a type of product quality.
  - A **constraint** is a property of the product (e.g., design decision) that is ordinarily not a requirement but which is being mandated as if it were a normal requirement

Quality Requirements

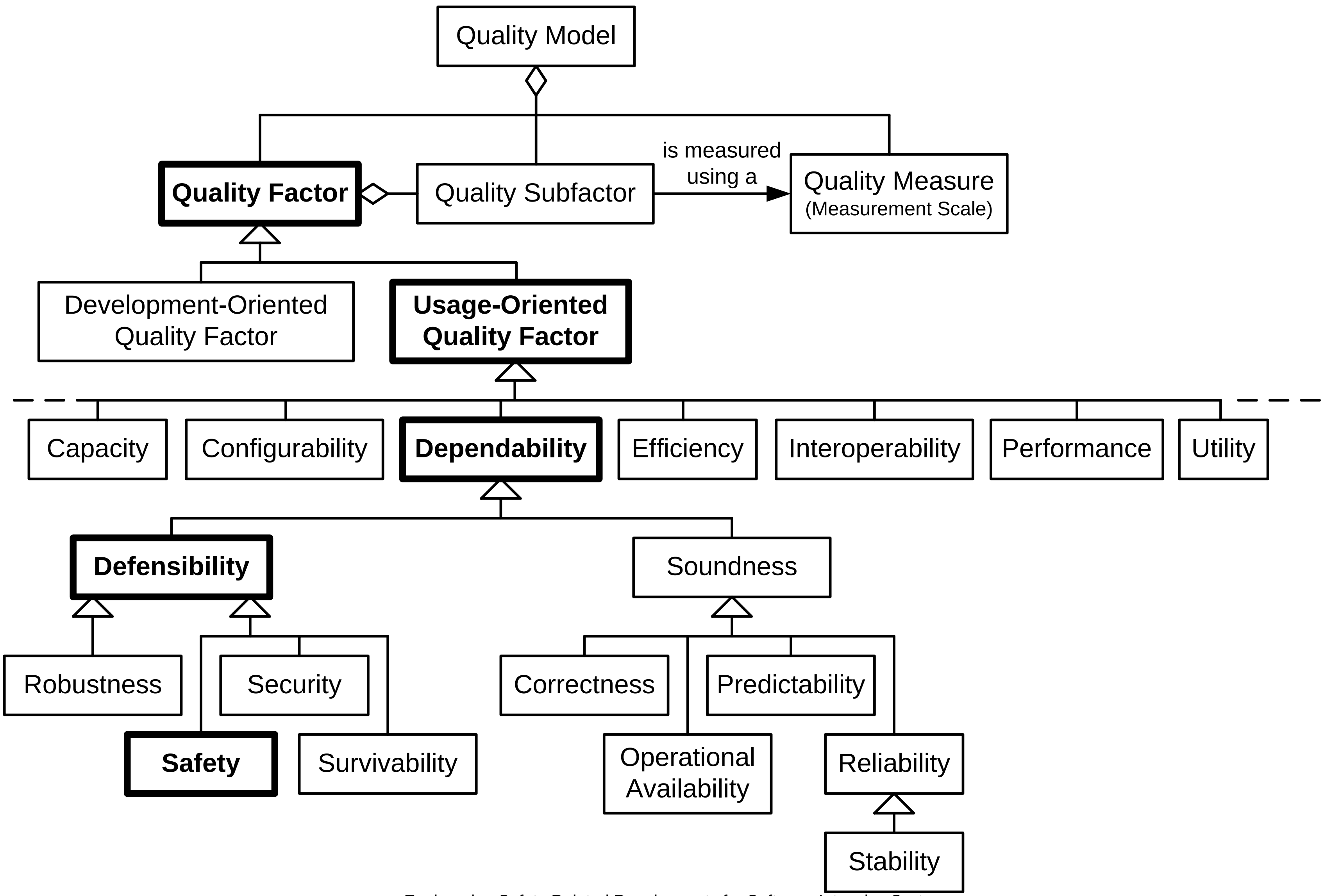
- A **quality requirement** is a product requirement that specifies a mandatory amount of a type of product quality.
  - Scalar (How Well or How Much?)
  - Based on Quality Model
  - Should be specified in requirements specifications.
  - Critically important drivers of the architecture

Quality Model

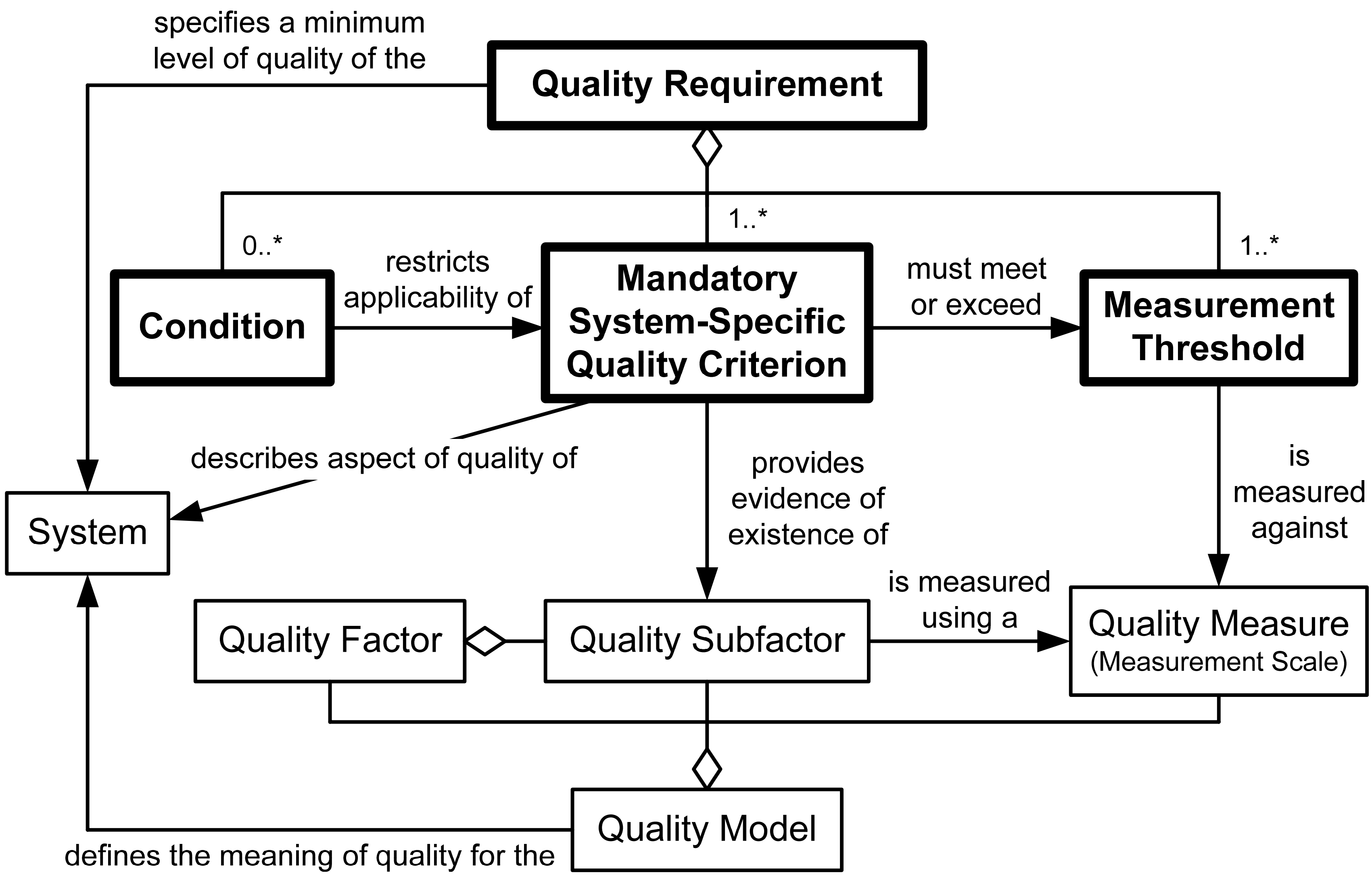
- A **Quality Model** is a hierarchical model (i.e., a collection of related abstractions or simplifications) for formalizing the concept of the quality of a system in terms of its quality factors, quality subfactors, and quality measures.



Many Different Quality Factors



Components of a Quality Requirement



Example Quality Requirement

- Hazard Prevention Safety Requirement:
  "Under normal operating conditions, a subway shall not move when one or more of it's doors are open more often than an average of once every 10,000 trips."
- Component Parts:
  - Condition:
    "Under normal operating conditions"
    (e.g., neither during maintenance nor fire)
  - Mandatory System-Specific Quality Criterion:
    "the subway shall move when one or more of it's doors are open
    (must define "move," "doors," and "open" somewhere)
  - Measurement Threshold:
    "not more often than an average of once every 10,000 trip."
    (A trip is defined as an intentional move from one station to the next station)

Importance of Measurement Threshold

- Measurement Threshold is:
  - Critical
  - Difficult (but not impossible) to determine
  - Often left out of quality requirements
  - Needed to avoid ambiguity
- States *how much* quality is necessary (adequate)
- Enables architect to:
  - Determine if architecture is adequate
  - Make engineering trade-offs between competing quality factors
- Enables tester to determine test completion criteria

Safety Engineering Overview

- **Safety engineering** is the *engineering discipline* within *systems engineering* that lowers the *risk* of *accidental harm to valuable assets* to an *acceptable level* to *legitimate stakeholders*.

Note:

- Engineering Discipline
- Systems Engineering (not just software)
- Risk
- *Accidental* Harm
- Harm to Valuable Assets
- *Acceptable Level* of Risk
- *Legitimate* Stakeholders

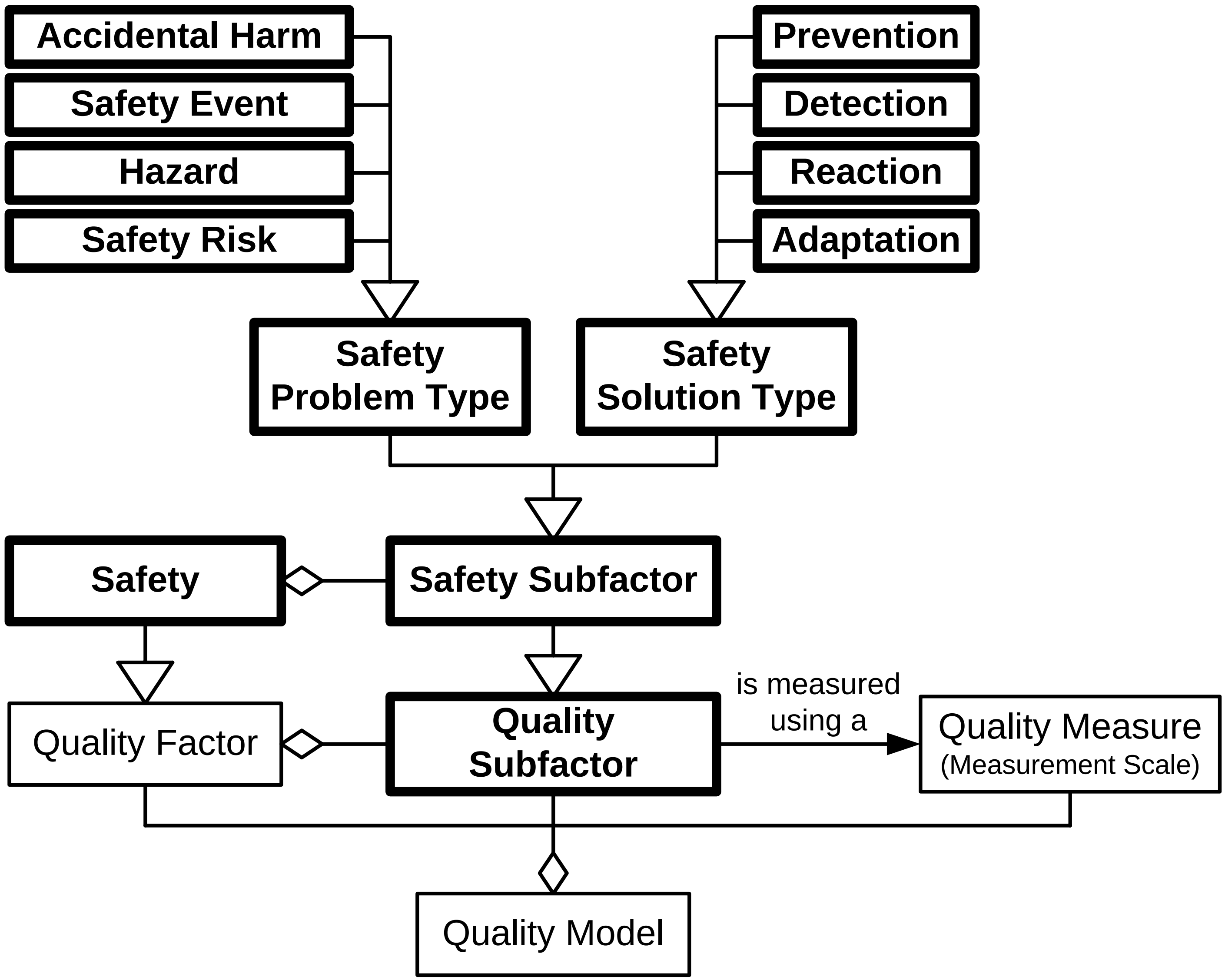
Basic Safety Concepts

- Safety as a Quality Factor of a Quality Model
- Safety Quality Subfactors
- Valuable Assets
- Accidental Harm to Valuable Assets
- Safety Events (Accidents, Incidents, and Hazardous Events)
- Hazards
- Safety Risks
- Goals, Policies, and Requirements
- Safeguards (Safety Mechanisms)

Safety as a Quality Factor

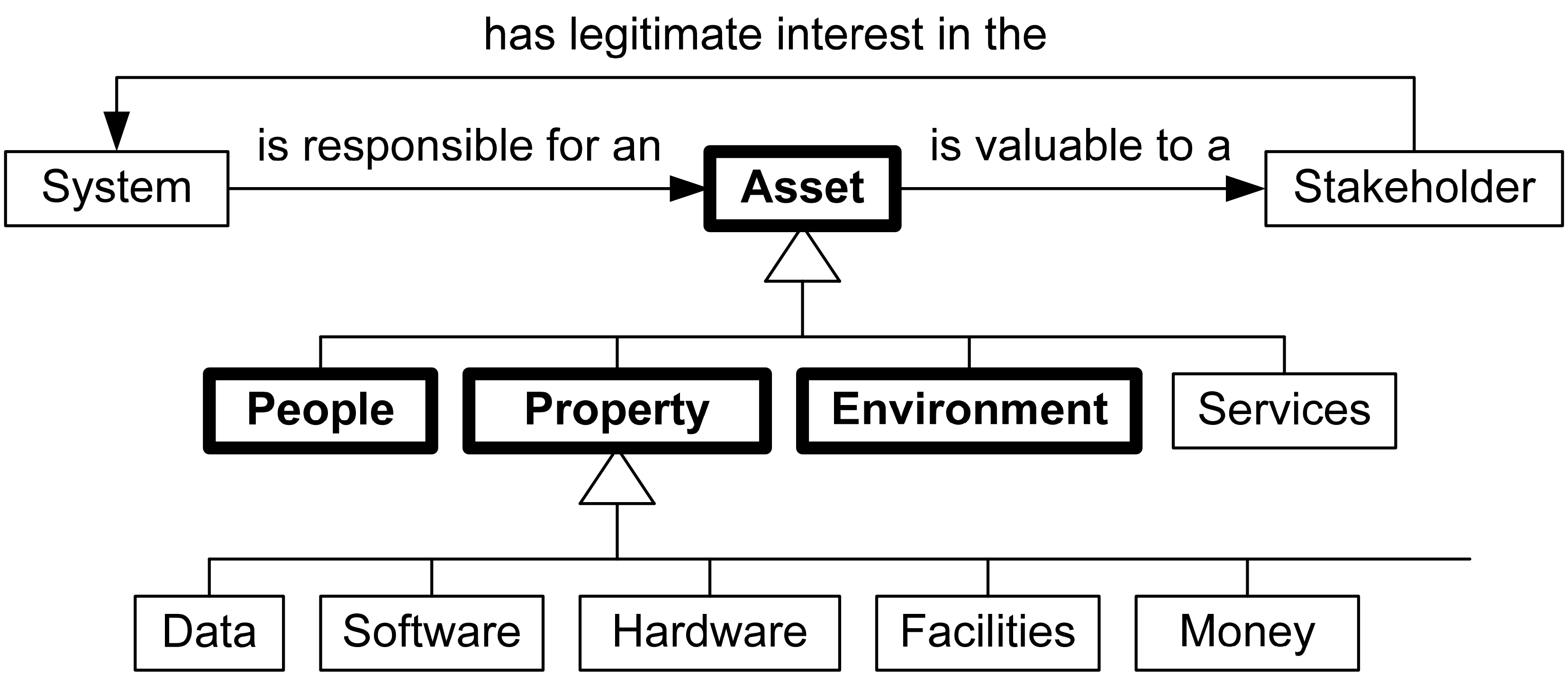
- **Safety** is the quality factor capturing the *degree* to which:
  - A*ccidental harm* to valuable assets is eliminated or mitigated
  - *Safety Events (Accidents, Incidents,* and *Hazardous Events*) are eliminated or their negative consequence mitigated
  - *Hazards* are eliminated or mitigated
  - *Safety risks* are kept acceptably low
  - The preceding problems are *prevented*, *detected*, *reacted to*, and possibly *adapted to*

Corresponding Safety Subfactors



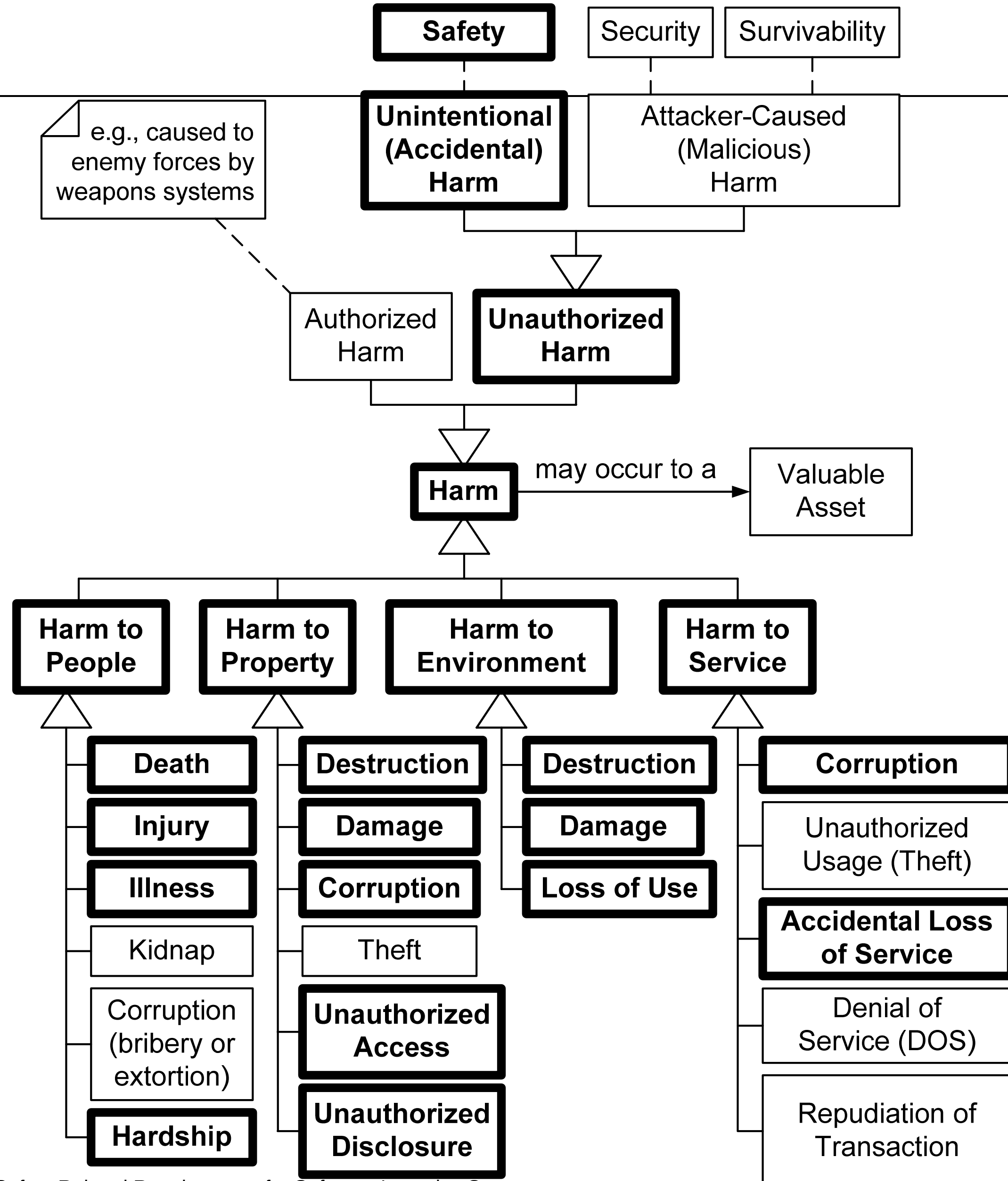
Valuable Assets

- A valuable **asset** is anything of *significant* value to a *legitimate stakeholder* that should be protected from *accidental* (or malicious) harm by the system.



Accidental Harm

- **Harm** is any significant negative consequence to a valuable asset
- **Accidental harm** is any unauthorized unintentional (i.e., non-malicious) harm (i.e., due to an accident)



Harm Severity

- **Harm severity** is an appropriate categorization of the amount of harm.
- Harm severity categories can be standardized (ISO, military, industry-wide) or endeavor-specific.
- Harm severity categories need to be:
  - Clearly identified.
  - Appropriately and unambiguously defined.

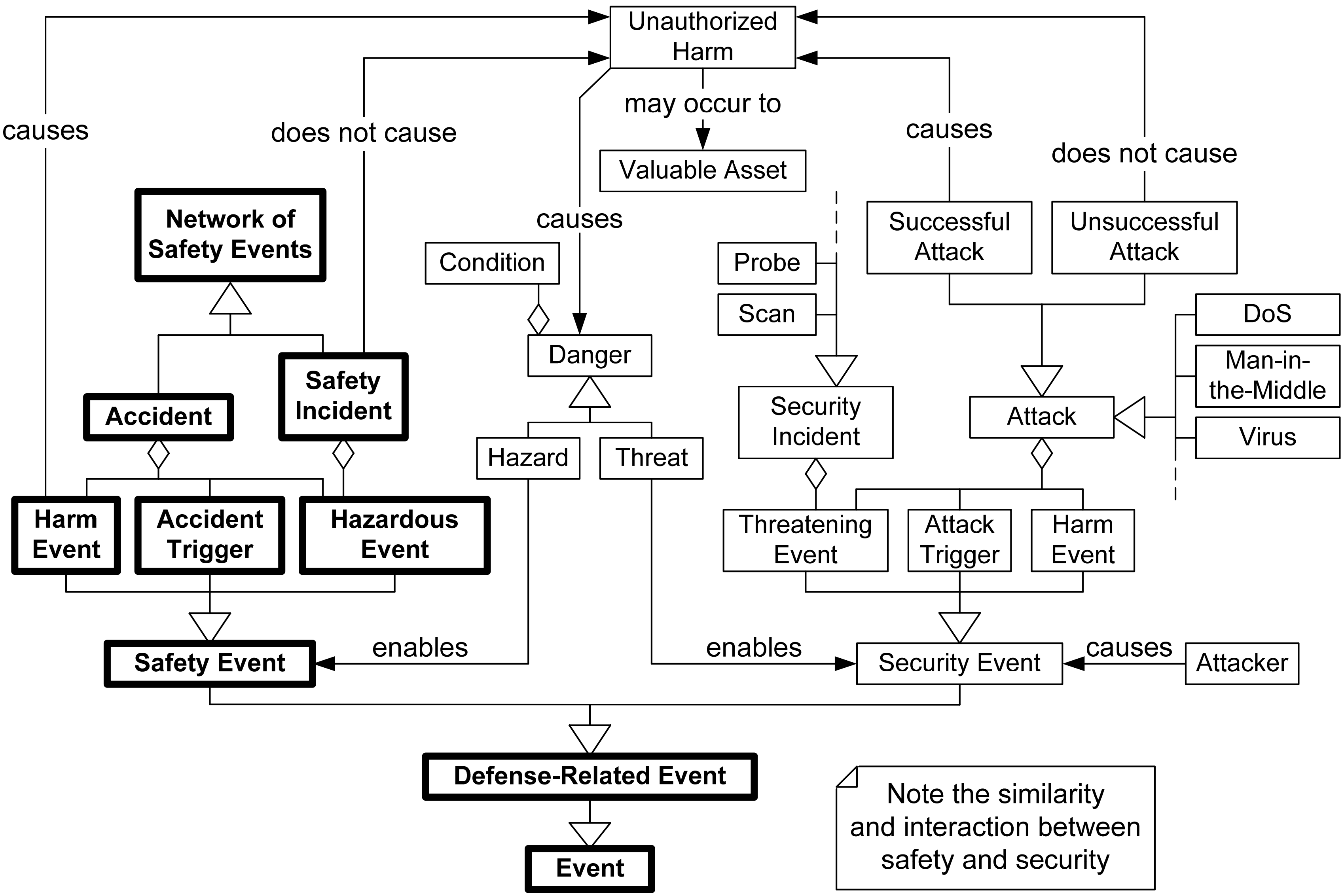
Example Harm Severity Categories

- Example from the commercial aviation standard, *Software Considerations in Airborne Systems and Equipment Certification* (RTCA/DO 178B: 1992):
  - **Catastrophic**:
    - Failure conditions, which prevent the continued safe flight and landing of the aircraft
  - **Severe-Major**:
    - Failure conditions, which reduce the capability of the aircraft or the ability of the crew to cope with adverse operation conditions
    - Serious or potentially fatal injuries to some passengers
  - **Major**:
    - Failure conditions, which reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions
    - Discomfort and possible injury to the passengers
  - **Minor**:
    - Failure conditions, which do not cause a significant reduction in aircraft safety
  - **No-Effect**:
    - Failure conditions, which do not effect the operational capability of the aircraft or increase the crew's workload

Safety-Related Events

- A **safety event** is any event with significant safety ramifications:
  - A **accident trigger** is a safety-related event that directly causes an accident.
  - A **harm event** is a safety-related event that causes significant harm.
  - A **hazardous event** is a safety-related event that causes the existence of a hazard (i.e., hazardous conditions).
- A **network of safety events** is any cohesive set of safety events:
  - An **accident** is a *series* of one or more related *safety events* causing actual non-malicious (i.e., accidental) harm to valuable assets.
  - A **safety incident** (a.k.a., **close call, near miss)** is a *series* of one or more related *hazardous events* that only by luck did not cause non-malicious actual harm.

Safety-Related Events and their Relationships



Importance of Accidents

- Accidents can have expensive and potentially fatal repercussions:
  - Ariane 5 Maiden Launch
    - Reuse of Ariane 4 software not matching Ariane 5 specification
  - Mars Climate Orbiter ($125 million)
    - English vs. Metric units mismatch
  - Mars Polar Lander
    - Missing requirement concerning touchdown sensor behavior
  - Therac–25 Radiation Therapy Machine
  - Patriot Missile Battery Misses SCUD
    - Missing availability (uptime) requirement

Poor Requirements Cause Accidents - 1

"The majority of software-related accidents are caused by requirements errors."

"Software-related accidents are usually caused by flawed requirements. Incomplete or wrong assumptions about the operation of the controlled system can cause software related accidents, as can incomplete or wrong assumptions about the required operation of the computer. Frequently, omitted requirements leave unhandled controlled-system states and environmental conditions."

Nancy G. Leveson, 2003

<http://www.safeware-eng.com/index.php/white-papers/accidents>

Poor Requirements Cause Accidents - 2

- Large percentage of accidents are caused by poor requirements:
  - “For the 34 (safety) incidents analyzed, 44% had inadequate specification as their primary cause.”

    Health and Safety Executive (HSE), *Out of Control: Why Control Systems Go Wrong and How to Prevent Failure* (2nd Edition), 1995

  - “Almost all accidents related to software components in the past 20 years can be traced to flaws in the requirements specifications, such as unhandled cases.”

    Safeware Engineering, “Safety-Critical Requirements Specification and Analysis using SpecTRM”*, 2002*

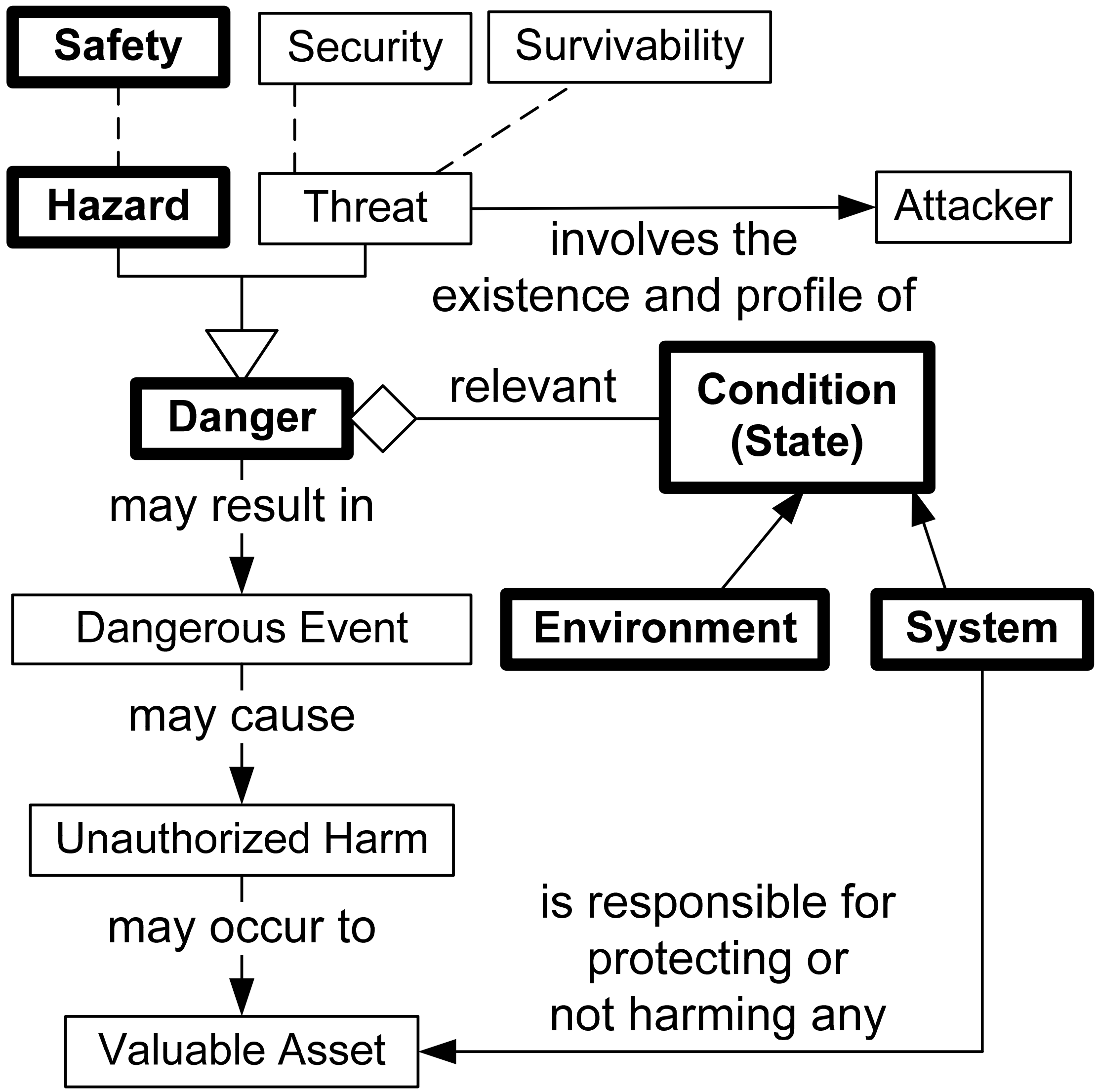
Safety Event Likelihood Categories

- **Safety Event Likelihood Categorization** is an appropriate categorization of the probability that a safety event occurs.
- Safety event likelihood categories:
  - Can be standardized (ISO, military, industry-wide) or endeavor-specific.
  - Need to be identified and defined.
- Example safety event likelihood categories include:
  - Frequent
  - Probable
  - Occasional
  - Remote
  - Implausible
- Safety event likelihood categories need to be carefully and unambiguously defined.

Safety Hazards

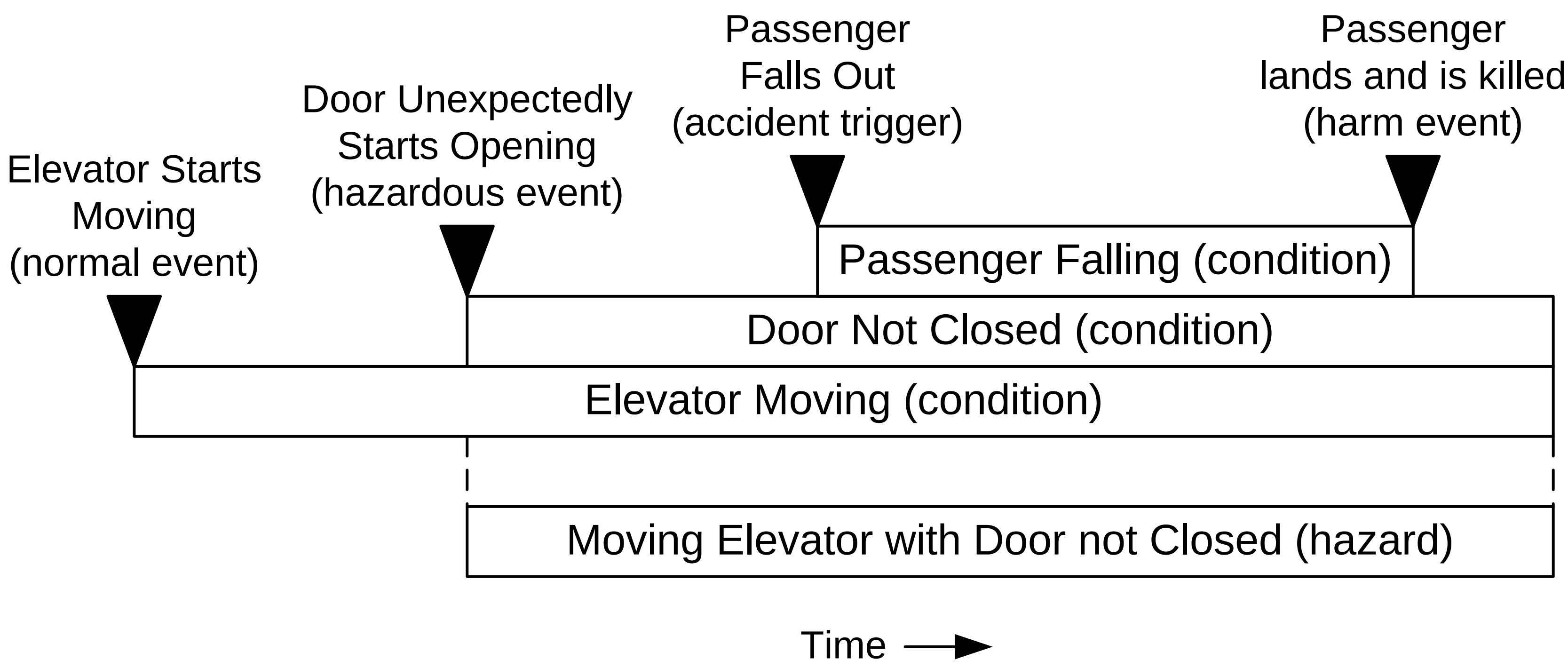
- **Danger** (Defensibility) is one or more conditions, situations, or states of a system that in conjunction with condition(s) in the environment of the system can cause or contribute to the occurrence of a *defense-related event*:
  - ***Hazard*** (Safety) is a danger that can cause or contribute to the occurrence of an *safety event*.
  - **Threat** (Security and Survivability) is a danger that can cause or contribute to the occurrence of a *security or survivability event* (e.g., a security vulnerability combined with an attacker with means, motive, and opportunity).

Hazards and their Relationships



Example Hazard, Events, Harm, and Asset

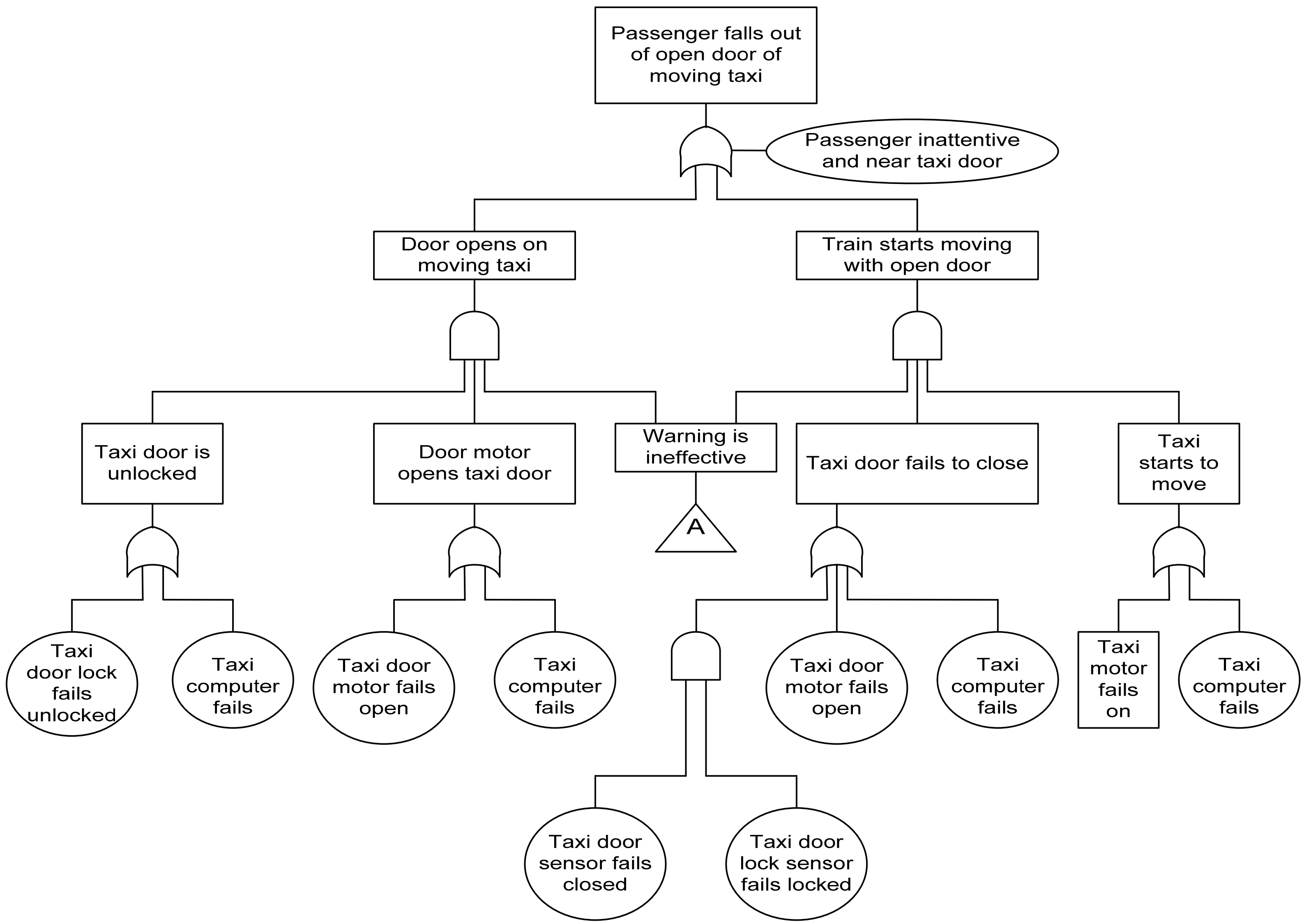
Passenger = valuable asset
Passenger death = harm to asset



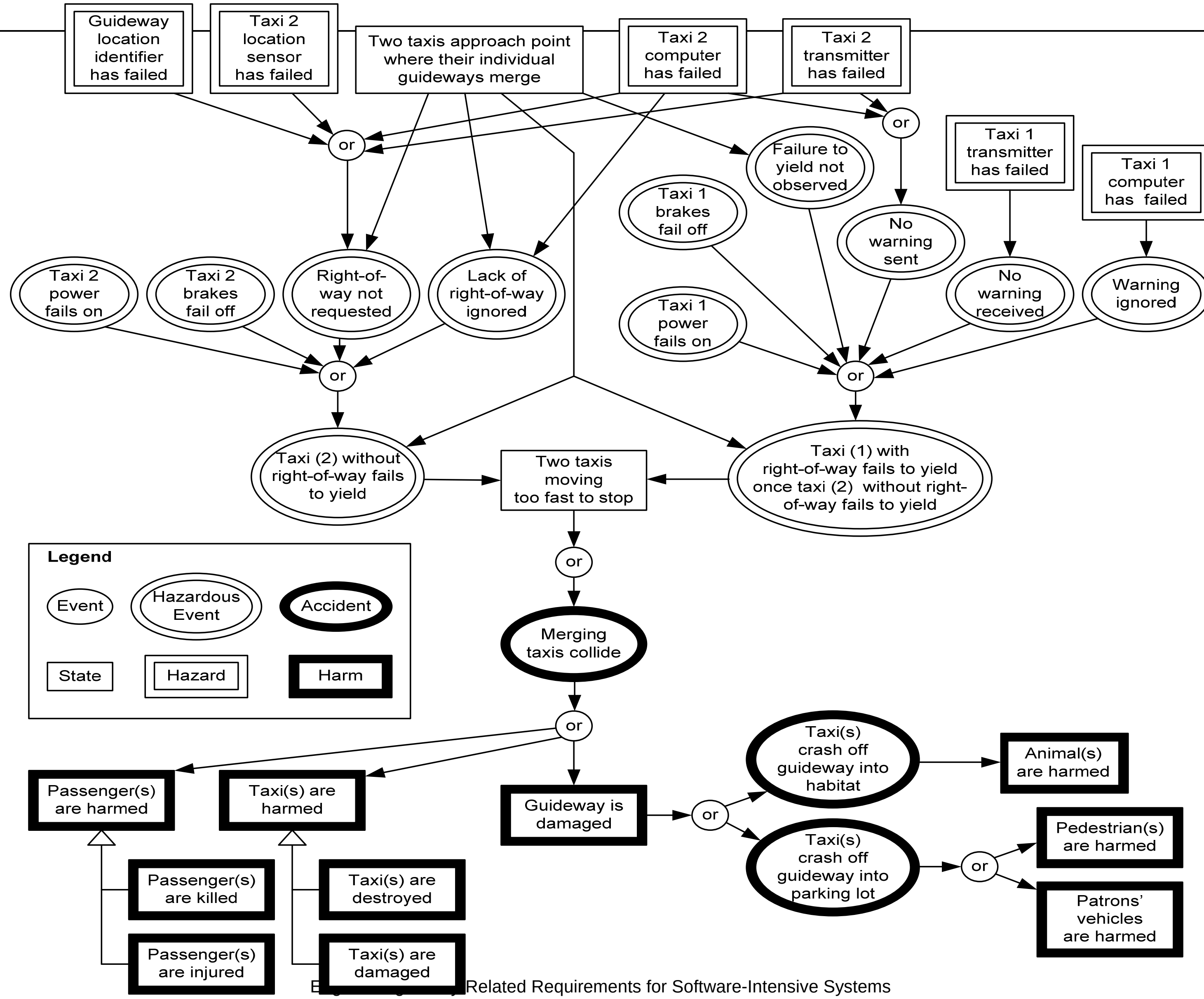
Hazard Analysis

- Hazard analysis usually implies the analysis of assets, harm, incidents, hazards, and risks.
- Hazard analysis often occurs multiple times before various milestones:
  - Preliminary Hazard Analysis
  - System Hazard Analysis
- Hazard analysis should probably be continuous.
- Fault Trees, Event Trees, and Cause/Effect Graphs can be used to determine potential causes and consequences of potential accidents and hazards.

Example Fault Tree (Cause of Failure)

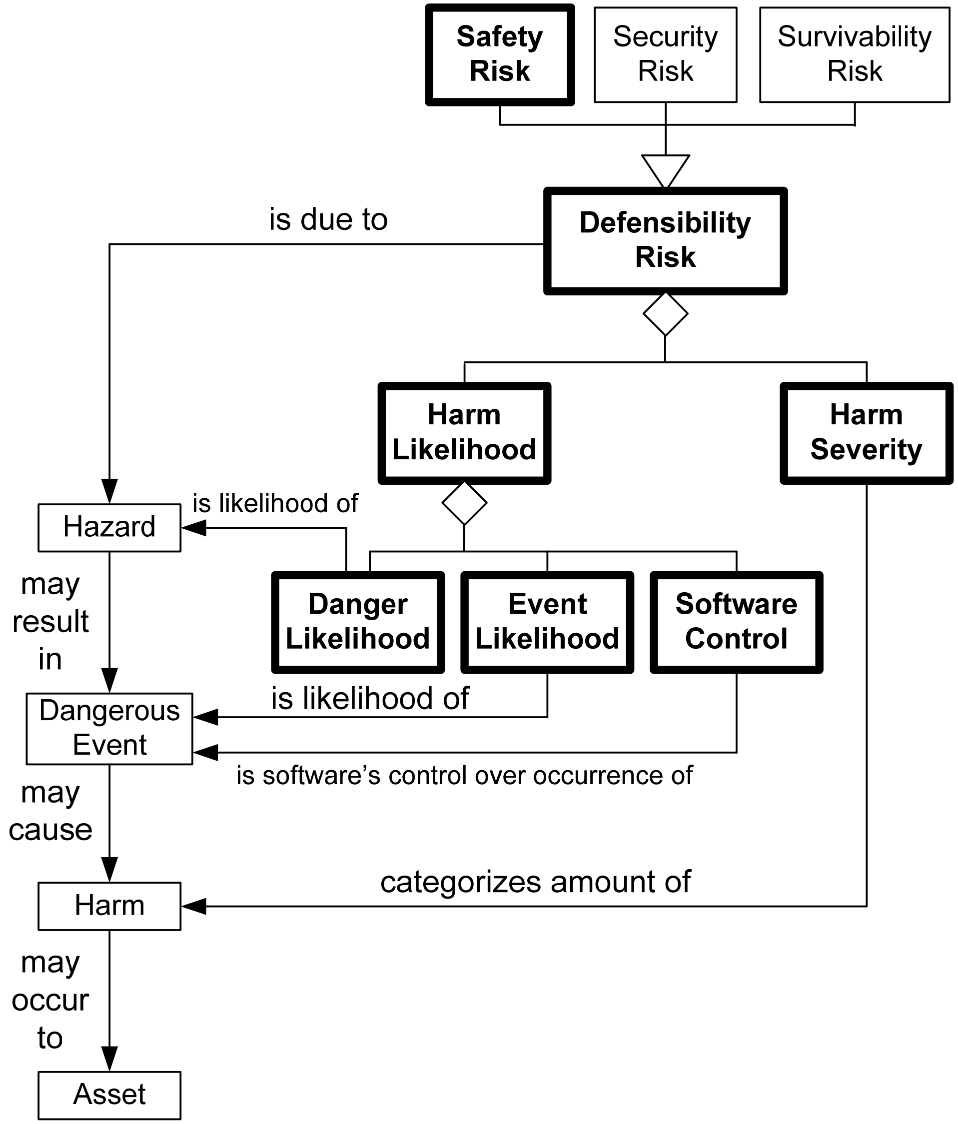


Example Cause/Effect Graph



Defensibility Risks including Safety Risks

- **Risk** is the combination of the severity of harm to a valuable asset with either the likelihood that the harm will occur or else the level of software control.
- **Harm severity** is usually set *conservatively* to the maximum credible category of harm.
- The likelihood of harm is the likelihood of danger multiplied by either the likelihood that the danger results in a harm-causing event (e.g., accident or attack).



Safety Integrity Levels (SILs)

- **Safety integrity levels (SILs)** are categories of requirements based on their associated safety risk level.
- SILs can be determined for:
  - Individual requirements.
  - Groups of related requirements (e.g., features or functions).
- SILs should be appropriately, clearly, and unambiguously defined.

Example Safety Integrity Levels (SILs)

- **Intolerable:**
  The risk associated with the requirement(s) is totally unacceptable to the major stakeholders. The requirement(s) *must* therefore be deleted or modified to lower the associated risk.
- **Undesirable:**
  The risk associated with the requirement(s) is so high that major (e.g., architecture, design, implementation, and testing) steps should be taken to lower the risk (e.g., risk mitigation and risk transfer) to lower the risk.
- **As Low As Reasonably Practical (ALARP):**
  Reasonable practical steps should be taken to lower the risk associated with the requirement(s).
- **Acceptable:**
  The risk associated with the requirement(s) is acceptable to the major stakeholders and no additional effort must be taken to lower it.

Example Safety Risk Matrix

- Safety Risk Matrix defines safety risk (and SIL) as a function of:
  - Harm severity
  - Accident/hazard frequency of occurrence.

Safety Risks / Safety Integrity Levels (SILs)					
	Frequency of Accident / Hazard Occurrence				
Harm Severity	**Frequent**	**Probable**	**Occasional**	**Remote**	**Implausible**
Catastrophic	Intolerable	Intolerable	Intolerable	Undesirable	ALARP
Critical	Intolerable	Intolerable	Undesirable	ALARP	ALARP
Major	Undesirable	Undesirable	ALARP	ALARP	Acceptable
Minor	Undesirable	ALARP	ALARP	Acceptable	Acceptable
Negligible	ALARP	ALARP	ALARP	Acceptable	Acceptable

Safety Goals

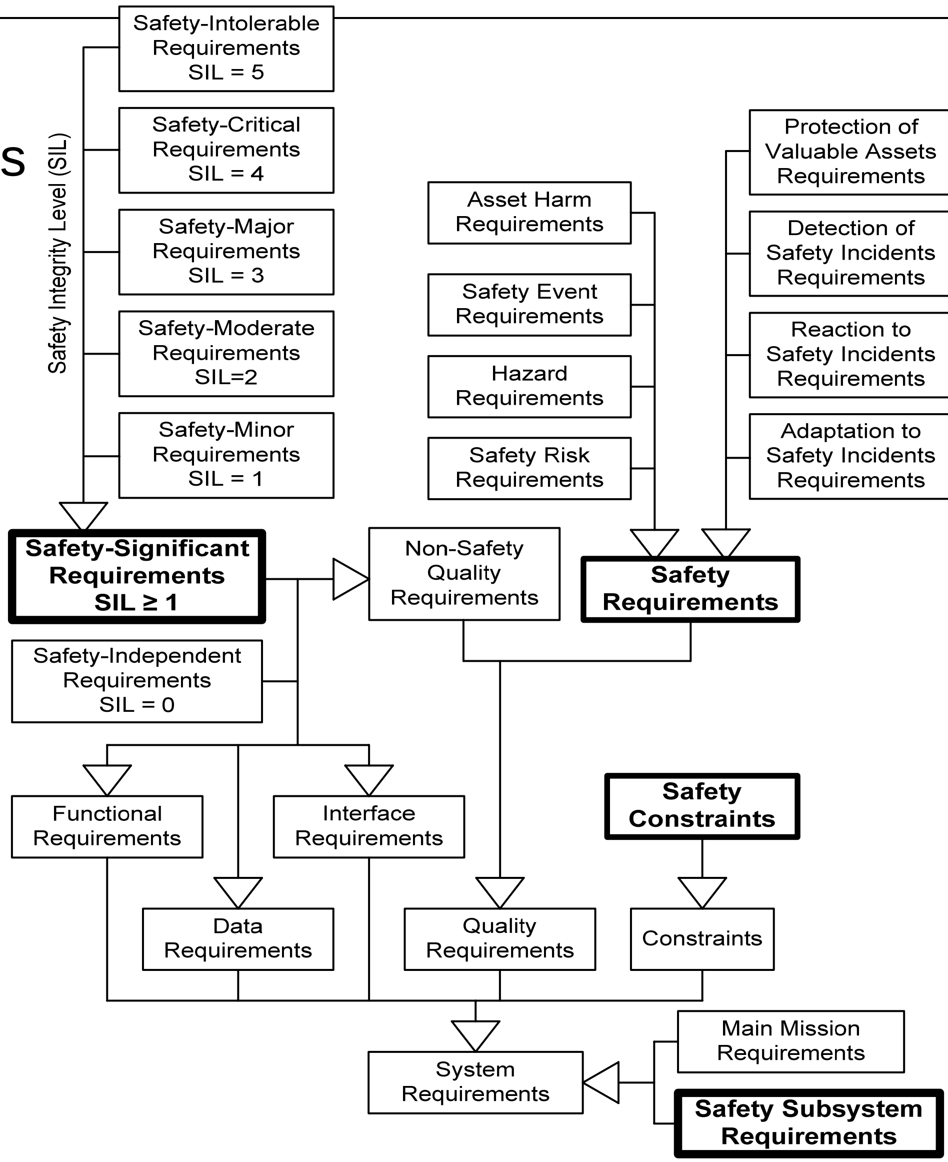
- **Safety Goals** are high-level stakeholder desires regarding safety:
  - "The system must be safe."
  - "There can be *no* serious accidents."
  - "The system will *never* kill or injure its users."
- Goals are typically unrealistic and unverifiable (i.e. impossible to guarantee 100% safety).
- Goals are *not* requirements.
- A *major* problem is safety goals that are specified as if they were verifiable requirements.

Safety Policies

- **Policy** – a strategic *process* decision that establishes a desired goal.
- **Safety policy** – a policy that enables the achievement of one or more *safety goals*:
  - "The overall responsibility for safety must be identified and communicated to all stakeholders."
  - "A hazard analysis shall be performed during early in the project."
  - "All users will have safety training."
- Safety policies are collected into safety policy documents.
- In practice, safety policies are confused with safety requirements, and conversely policy documents may sometimes include safety requirements.

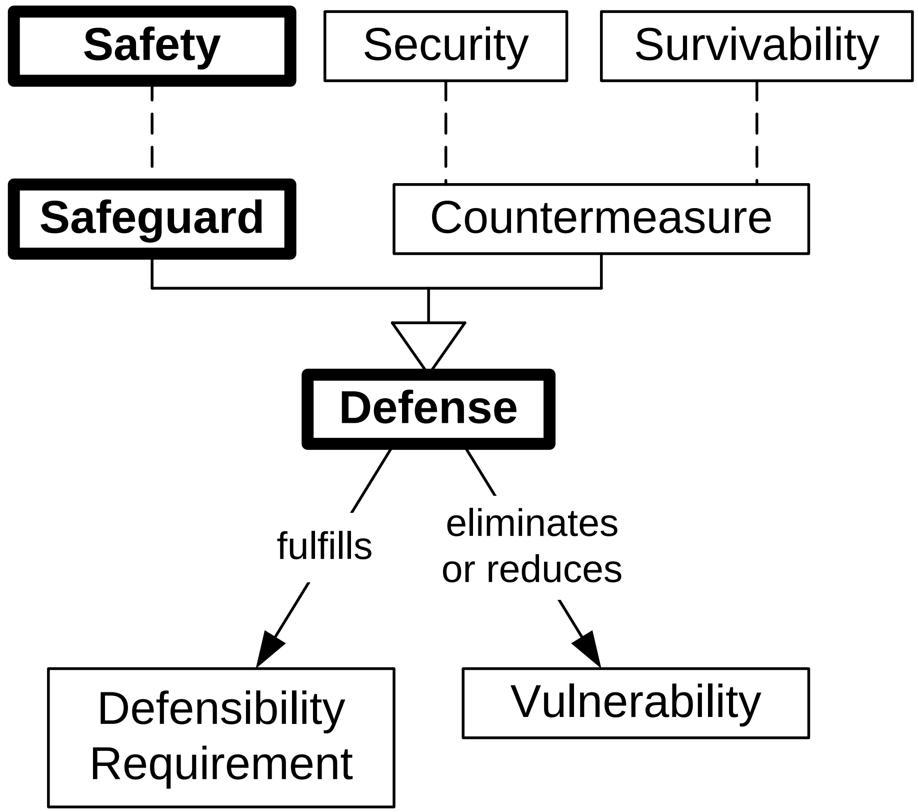
Safety-Related Requirements

- A **safety-related requirement** is a *product* requirement that has significant *safety ramifications*.
- Safety-related requirements include:
  - Safety Requirements
  - Safety-Significant Requirements
  - Safety Subsystem Requirements
  - Safety Constraints



Safeguards (Safety Control, Safety Mechanism)

- A **safeguard** is a kind of defense that helps fulfill a safety-related requirement and thereby eliminates or reduces the impact of a safety vulnerability.
- A safeguard is a part of the system (e.g., component, procedure, training)
- Only relevant to requirements if specified as safety constraints.



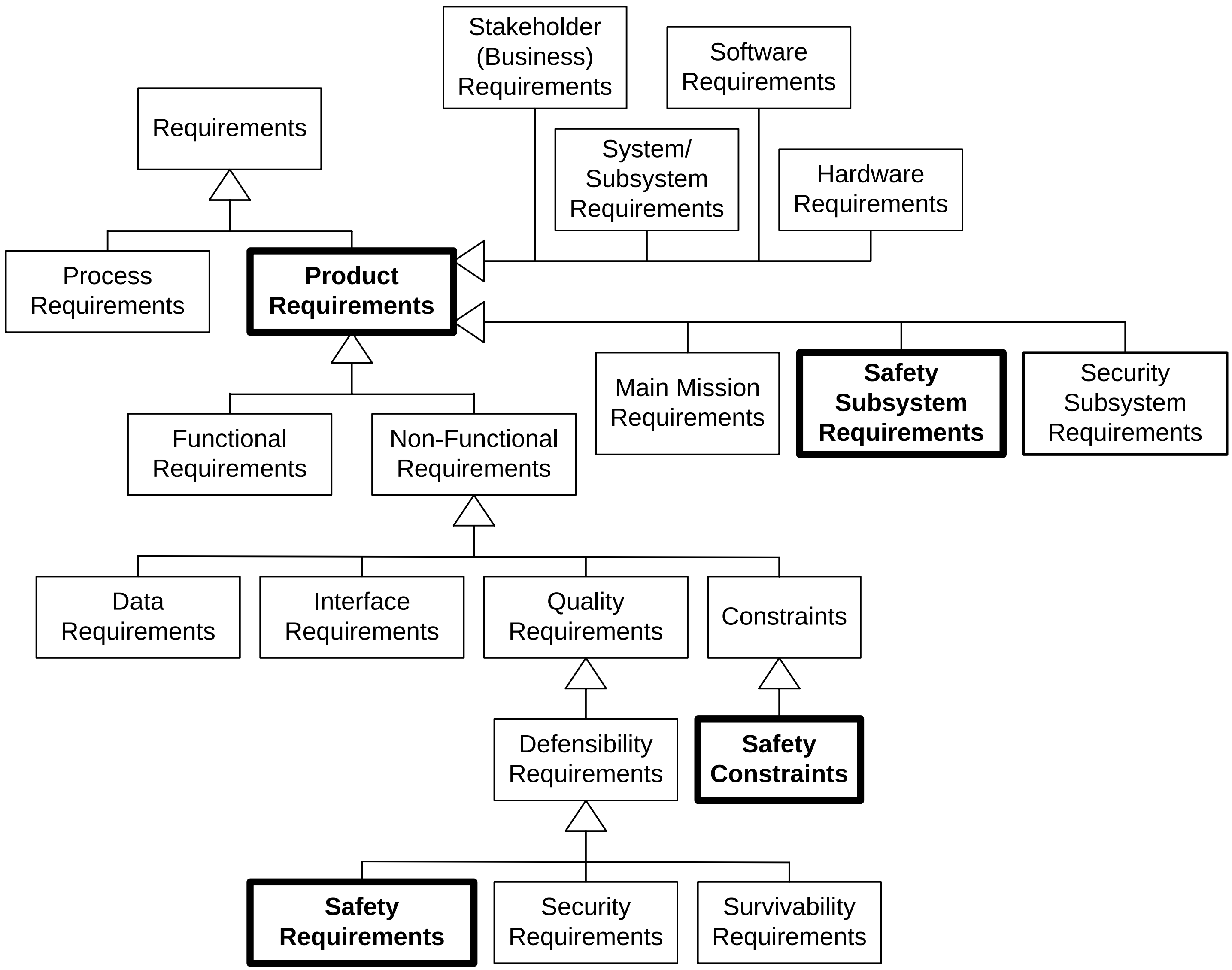
Safety-Related Requirements

- Safety Requirements
- Safety-Significant Requirements
- Safety Subsystem Requirements
- Safety Constraints

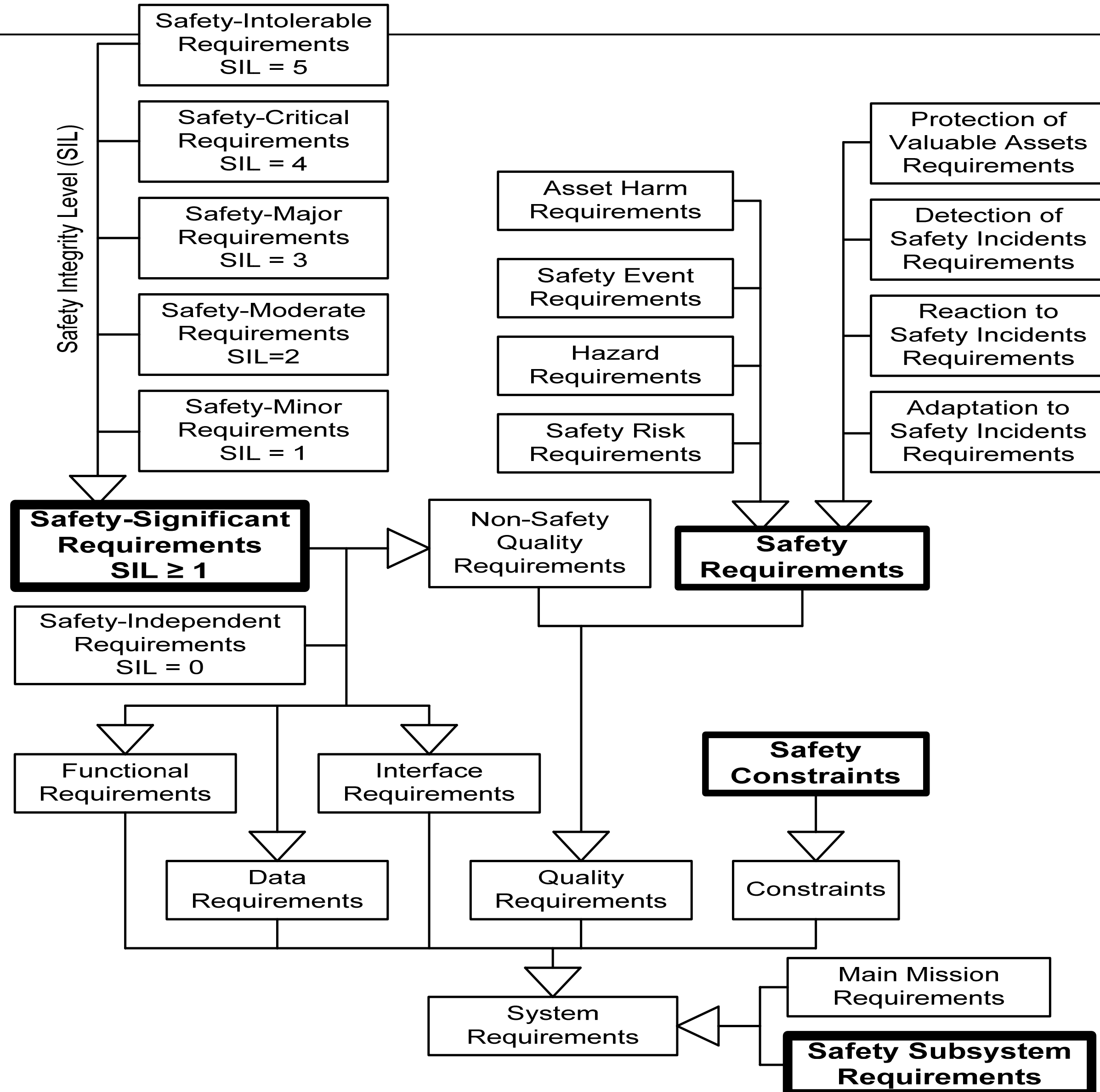
Safety-Related Requirement Definitions

- ***Safety-Related Requirements*** are any system requirements having *significant safety ramifications*:
  - **Safety Requirements** are requirements that specify mandatory minimum safety levels in terms of pairs of subfactors of the safety quality factor.
  - **Safety-Significant Requirements** are *non-safety primary mission* requirements with significant safety ramifications.
  - **Safety Subsystem Requirements** are requirements for safety subsystems (as opposed to primary mission requirements).
  - **Safety Constraints** are constraints intended to ensure a minimum level of safety.

Types of Requirements



Safety-Related Requirements

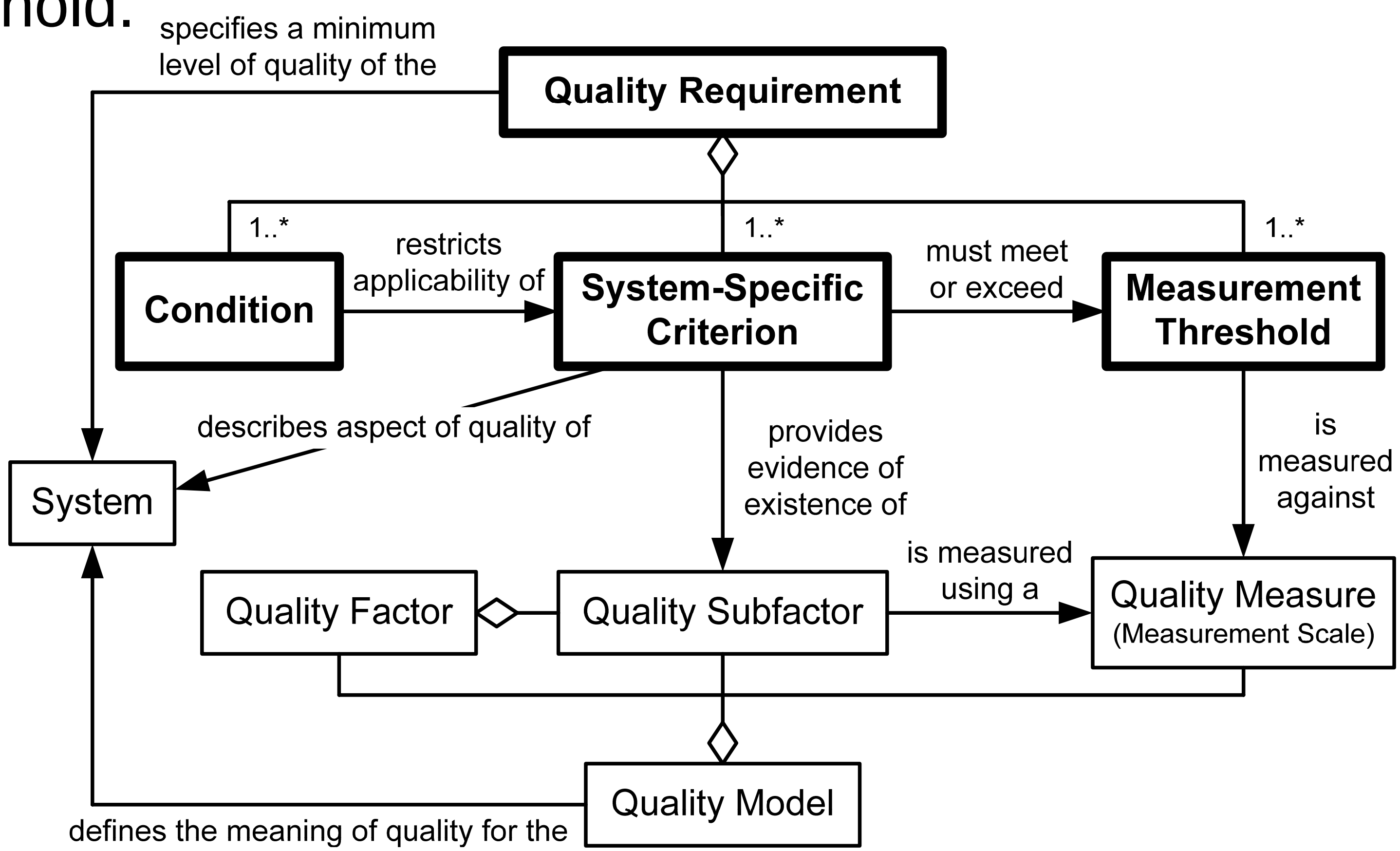


[Pure] Safety Requirements

- A safety requirement is a kind of *quality (defensibility) requirement* because safety is a kind of defensibility. (Safety requirements are like security requirements.)
- Safety requirements specify *minimum required amounts* of:
  - Safety
  - Two quality subfactors of safety:
    - Defensibility Problem Type:
      Accidental Harm, Safety Event, Hazard, Safety Risk
    - Defensibility Solution Type:
      Prevention, Detection, Reaction, Adaptation

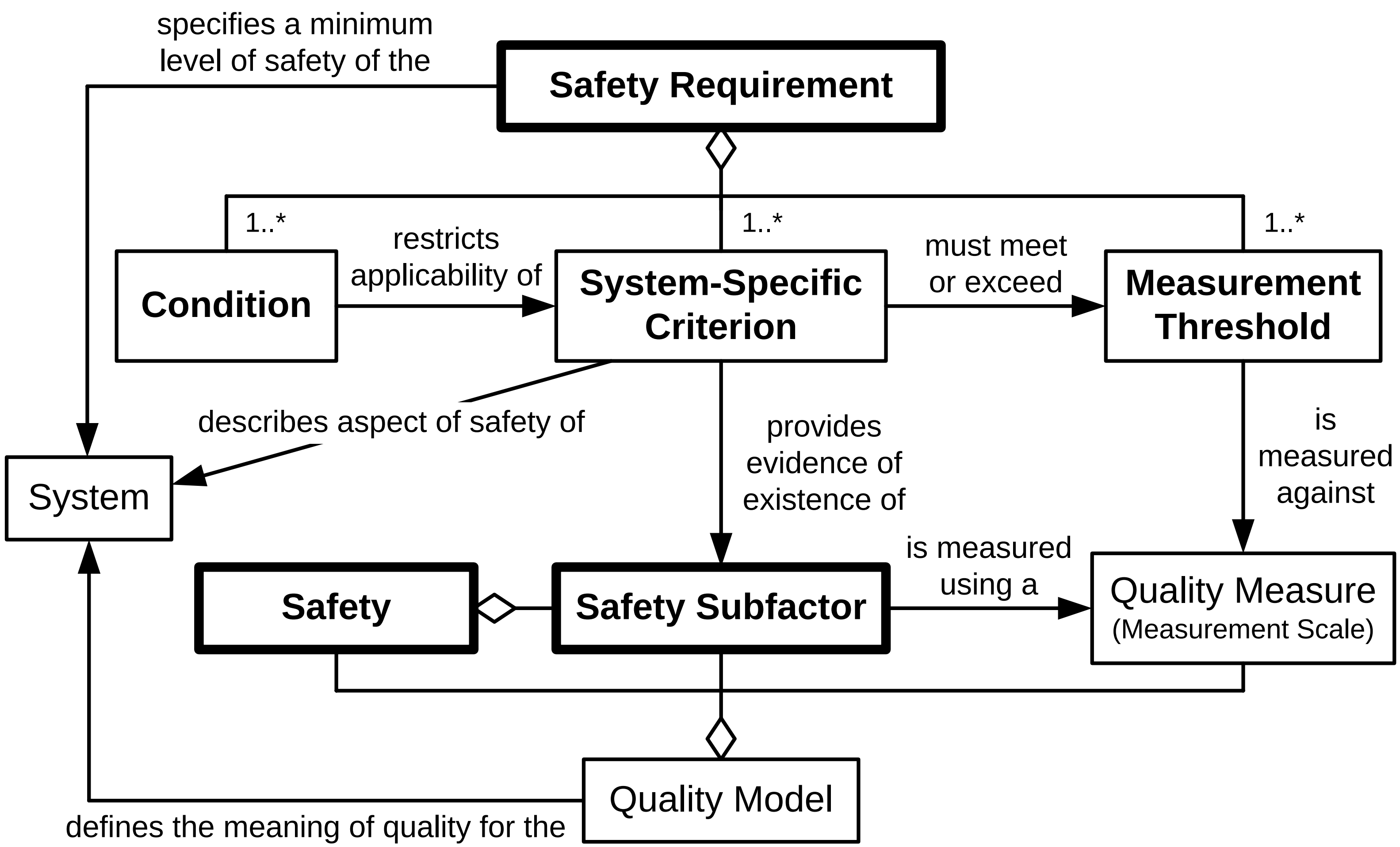
Quality Requirements

- A quality requirement is composed of conditions, a system-specific criterion, and a required measurement threshold.

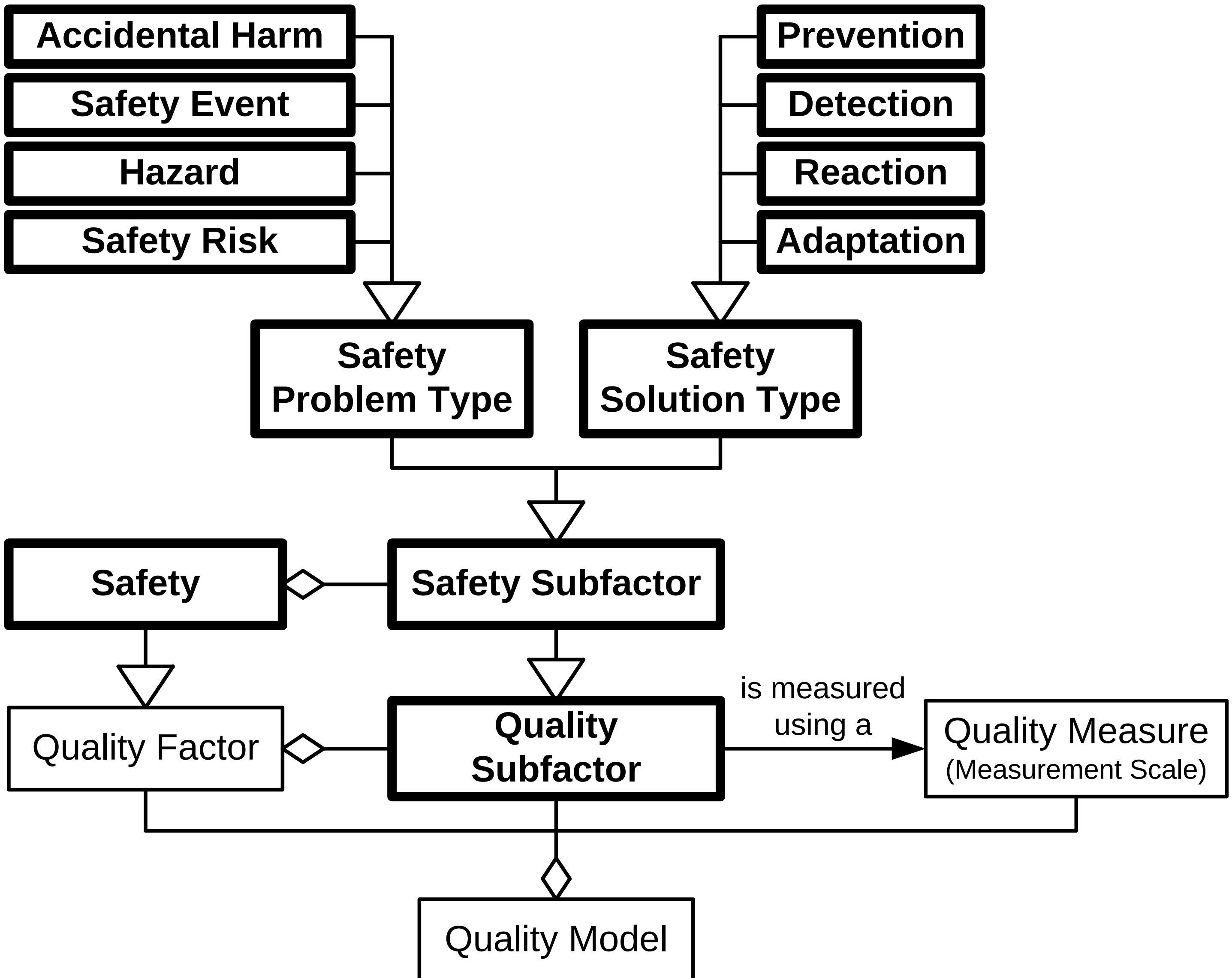


Safety Requirements

- Safety Requirements are a kind of quality requirement.



Based on Safety Subfactors



Sixteen Types of Safety Requirements

	Accidental Harm	Safety Event	Hazard	Safety Risk
Prevention	Prevent accidental harm	Prevent safety event	Prevent existence of hazard	Prevent existence of safety risk
Detection	Detect accidental harm	Detect safety event	Detect existence of hazard	Detect existence of safety risk
Reaction	React to accidental harm	React to safety event	React to existence of hazard	React to existence of safety risk
Adaptation	Adapt due to accidental harm	Adapt due to safety event	Adapt due to existence of hazard	Adapt due to existence of safety risk

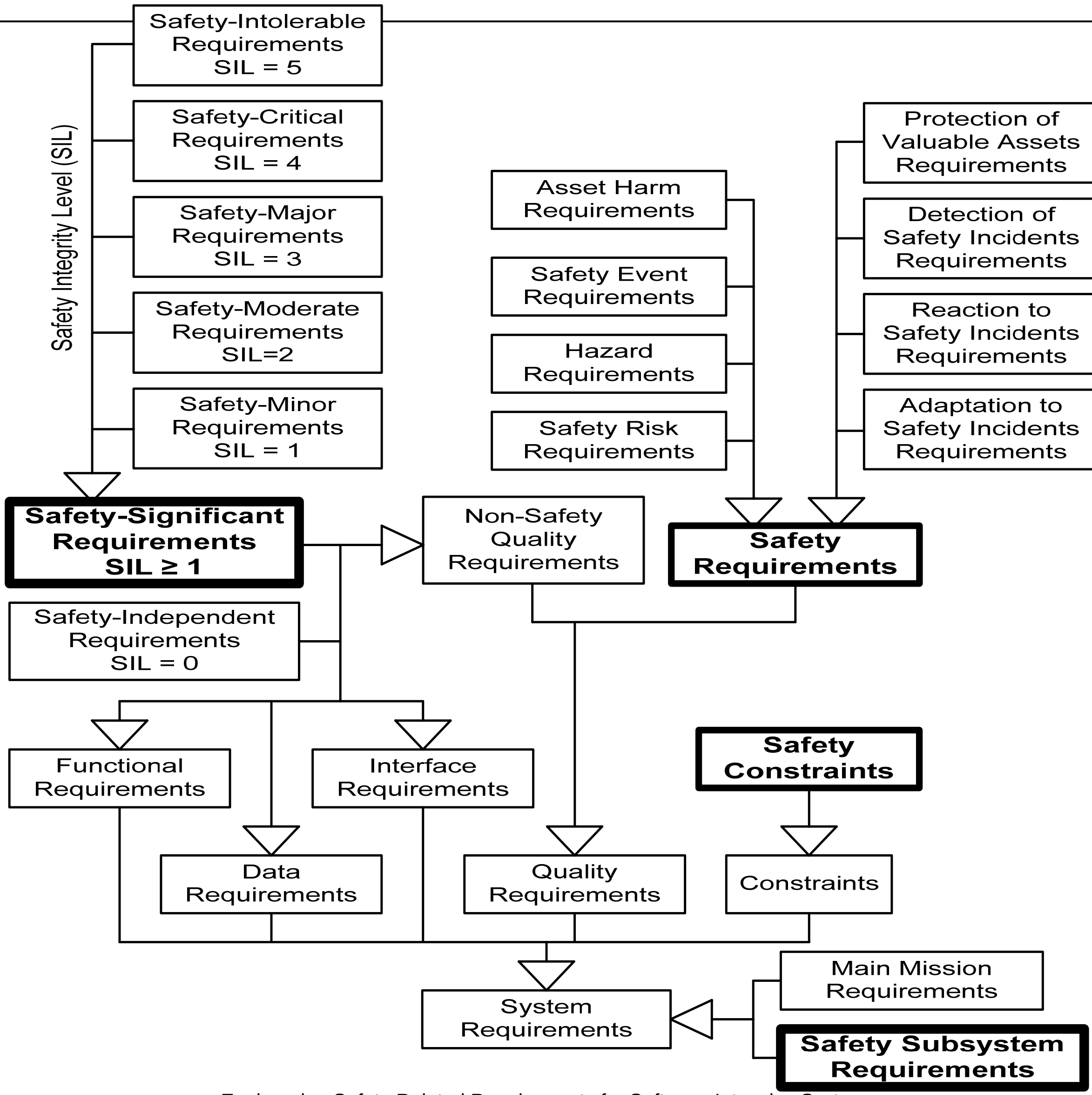
Example Safety Requirements

- “With 99% confidence, the system shall not cause more than X amount of *accidental harm* per year.”
- “With 99% confidence, the system shall not cause more than X *safety incidents* (accidents, near misses) per passenger mile traveled.”
- “With 99% confidence, the system shall not under normal conditions cause *hazard* X to exist more than Y percent of the time.”
- “The system shall not allow a *safety risk level* of X to exist.”
- “The system shall *detect accidents* of type X at least Y percent of the time.”
- “Upon detecting an accident of type X, the system shall *react* by performing Y at least Z percent of the time.”

Safety-Significant Requirements

- Are identified based on safety (hazard) analysis
- Subset of non-safety requirements:
  - Functional Requirements
  - Data Requirements
  - Interface Requirements
  - Non-safety Quality Requirements
  - Constraints
- Safety Integrity Level (SIL) is not 0:
  - May have minor safety ramifications
  - May be safety-critical
  - May have intolerable safety risk

Safety-Related Requirements



SILs and SEALs

- **Safety Integrity Level (SIL)** – a category of required safety for safety-significant requirements.
- **Safety Evidence Assurance Level (SEAL)** – a category of required evidence needed to assure stakeholders (e.g., safety certifiers) that the system is sufficiently safe (i.e., that it has achieved its required SIL).
- **SILs** are for *requirements*
- **SEALs** are for *components* that collaborate to fulfill requirements (e.g., *architecture*, design, coding, testing)
- SILs do not map 1-1 to SEALS.

Safety-Significant Requirements (cont)

- Require enhanced Safety Evidence Assurance Levels (SEALs) including more rigorous development process (including better requirements engineering):
  - Formal specification of requirements
  - Fagan inspections of requirements
- Too often SEALs only apply to design, coding, and testing:
  - Safe subset of programming language
  - Design inspections
  - Extra testing

Example Safety-Significant Requirements

- Requirements for controlling subway doors:
  - Keep doors closed when moving
  - Not crush passengers
- Requirements for firing missiles from military aircraft:
  - When to arm missile
  - Controlling doors providing stealth capabilities
  - Detecting weight-on-wheels
- Requirements for chemical plant:
  - Mixing and heating chemicals
  - Detecting temperature and pressure

Safety Subsystem Requirements

- **Safety Subsystem Requirements** are requirements for safety subsystems (as opposed to primary mission requirements).
- Subsystems or components strictly added for safety:
  - Aircraft Safety Subsystems:
    - Collision Avoidance System
    - Engine Fire Detection and Suppression
    - Ground Proximity Warning System (GPWS)
    - Minimum Safe Altitude Warning (MSAW)
    - Wind Shear Alert
  - Nuclear Power Plant:
    - Emergency Core Coolant System
- All requirements for such systems are safety-related.

Example Safety Subsystem Requirements

- “Except when the weapons bay doors are open or have been open within the previous 30 seconds, the weapons bay cooling subsystem shall maintain the temperature of the weapons bay below X° C.”
- “The Fire Detection and Suppression Subsystem (FDSS) shall detect smoke above X ppm in the weapons bay within 2 seconds at least 99.9% of the time.”
- “The FDSS shall detect temperatures above X° C in the weapons bay within 2 seconds at least 99% of the time.”
- “Upon detection of smoke or excess temperature, the FDSS shall begin fire suppression within 1 second at least 99.9% of the time.”

Safety Constraints

- A **constraint** is any engineering decision that has been chosen to be mandated as a requirement. For example:
  - Architecture constraints
  - Design constraints
  - Implementation constraints
    (e.g., coding standards or safe language subset)
  - Testing constraints
- A **safety constraint** is any constraint primarily intended to ensure a minimum level of safety
  (e.g., a mandated safeguard).
- Safety standards often mandate best practices as safety constraints.

Example Safety Constraints

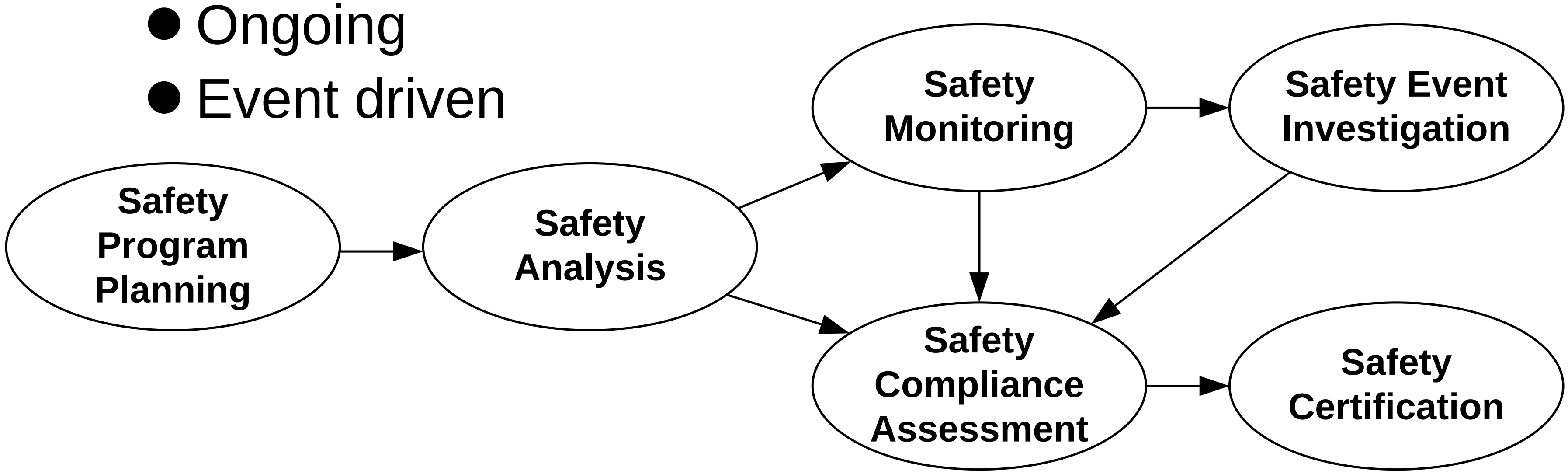
- “When the vehicle is stopped in a station with the doors open for boarding, the horizontal gap between the station platform and the vehicle door threshold shall be no greater than 25 mm (1.0 in.) and the height of the vehicle floor shall be within plus/minus 12 mm (0.5 in.) of the platform height under all normal static load conditions…” Automated People Mover Standards – Part 2: Vehicles, Propulsion, and Braking (ASCE 21-98)
- “Oils and hydraulic fluids shall be flame retardant, except as required for normal lubrication.”

Recommended Combined Method

- How should *safety-related requirements* be *engineered*?
- Need to combine (include) tasks, teams, and work products from:
  - **Requirements Engineering**
  - **Safety Engineering**
- What is appropriate?
  - What tasks need to be performed?
  - Who should perform them?
  - What collaboration is appropriate/necessary?
  - What work products should be produced?
  - Where do requirements work products fit in?

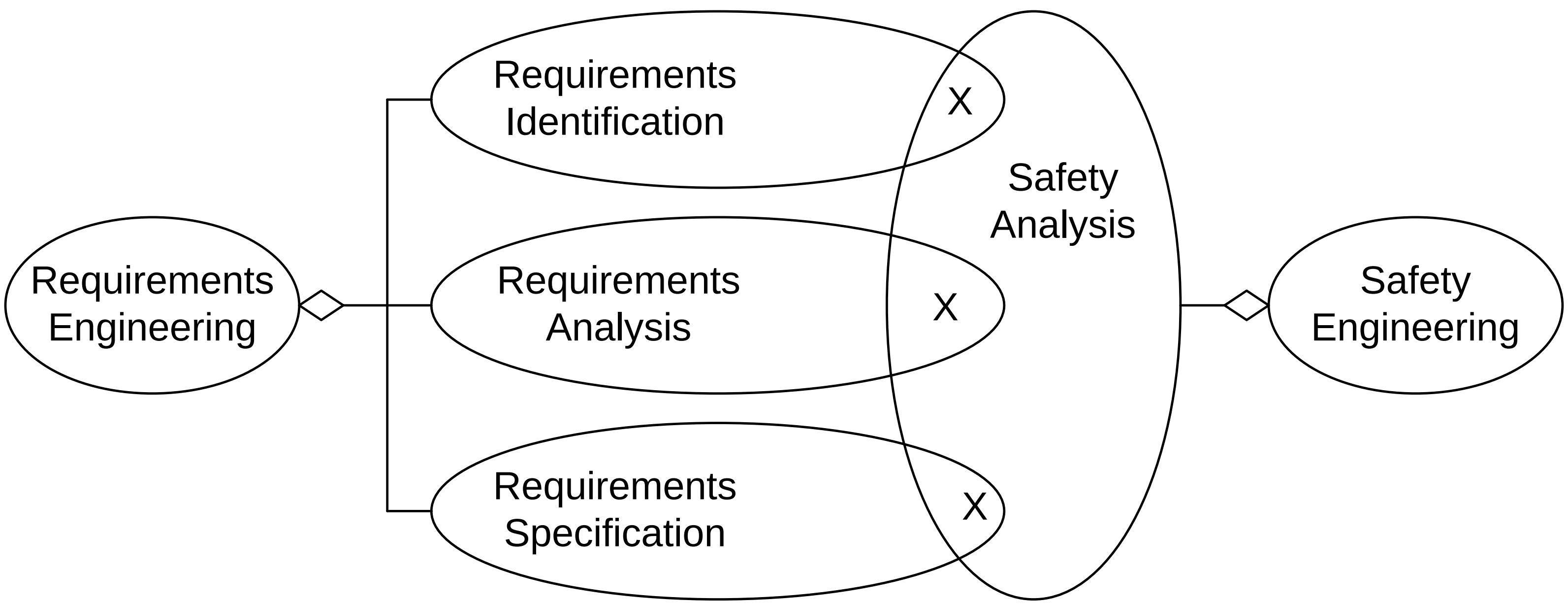
Basic Safety Engineering Tasks

- Six basic safety engineering tasks.
- Not all directly related to engineering safety-related requirements.
- Some tasks are:
  - Up front
  - Ongoing
  - Event driven

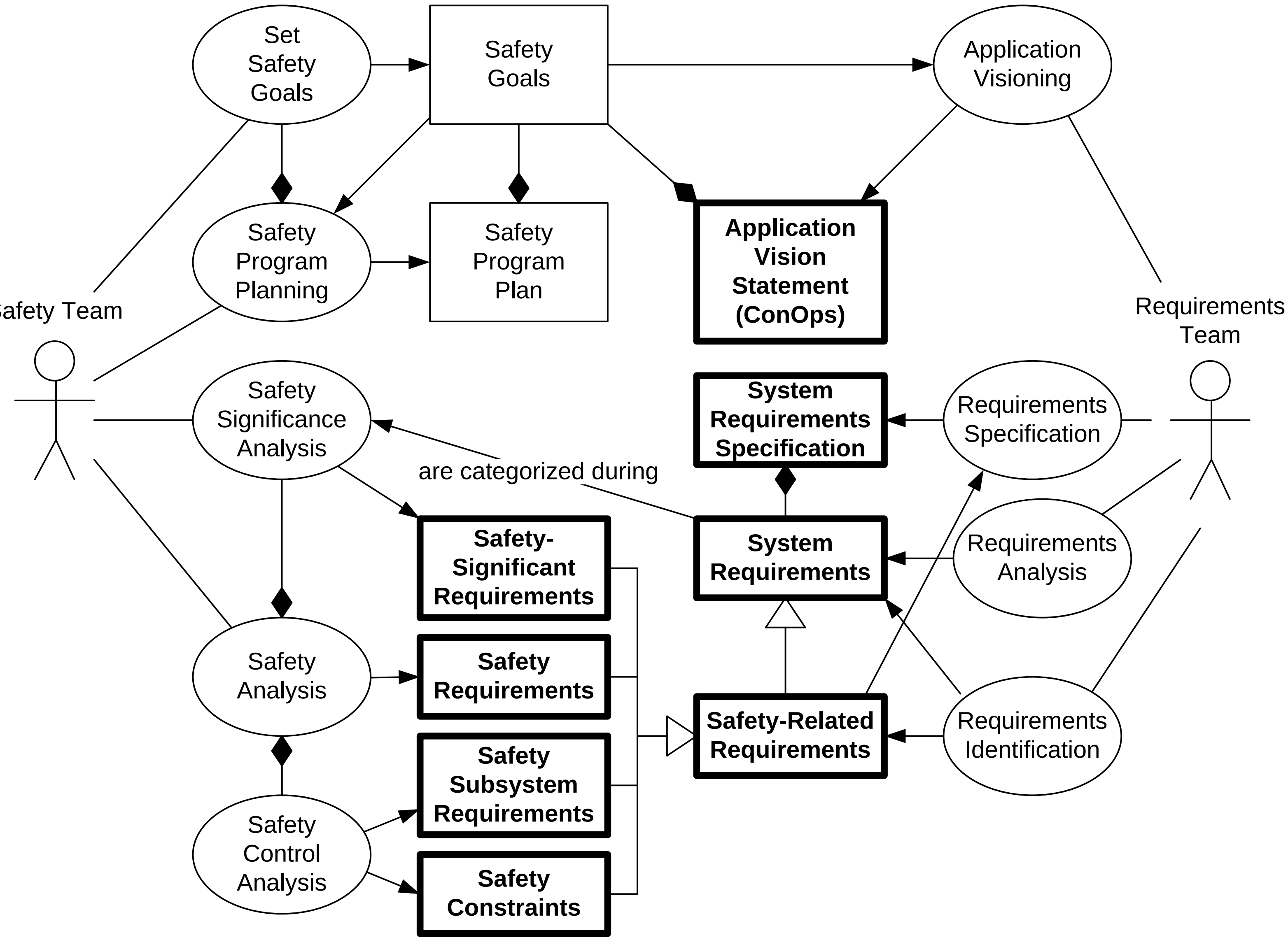


Overlap between RE and SE

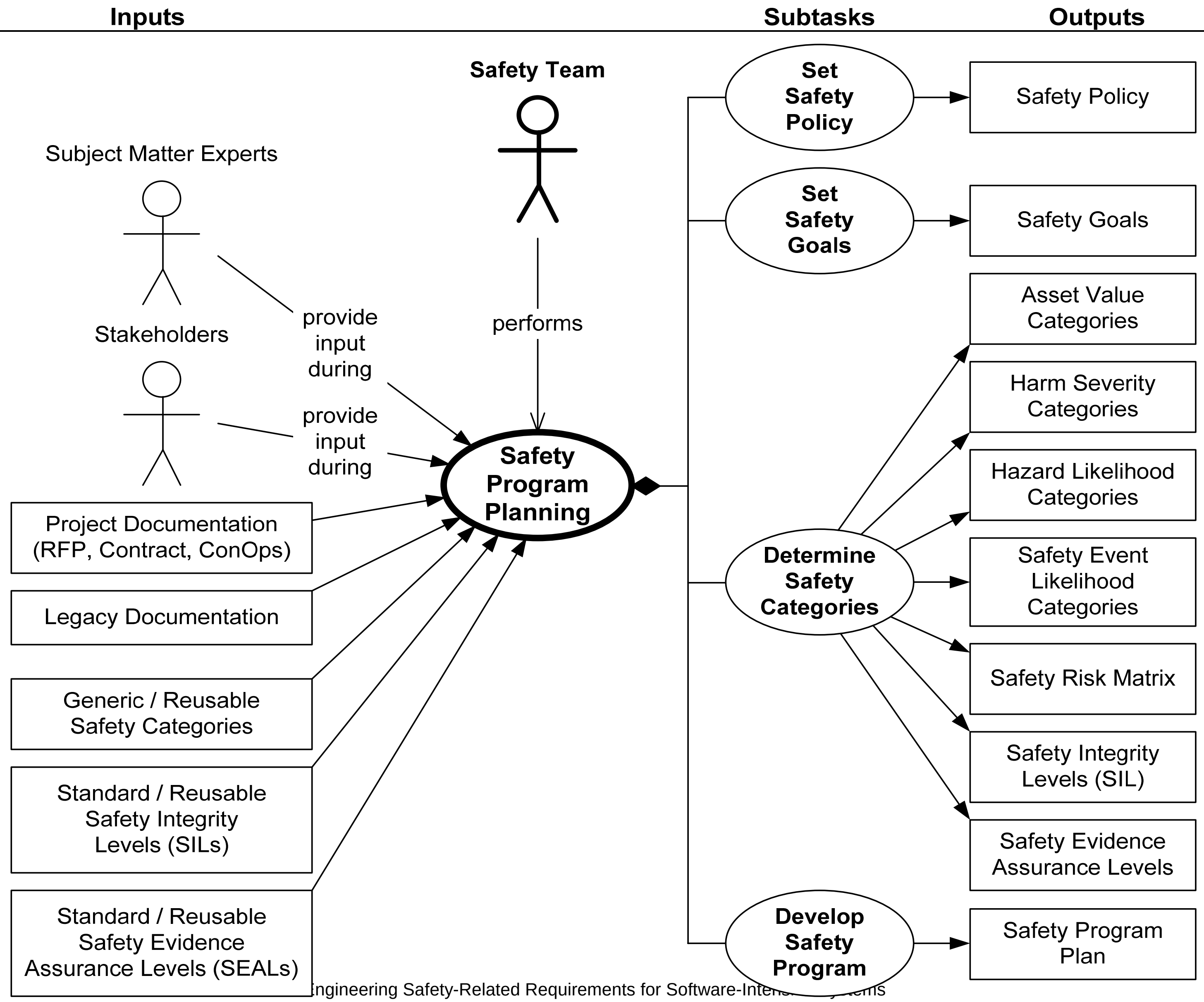
- Requirements Engineering includes:
  - Requirements Identification
  - Requirements Analysis
  - Requirements Specification
- Safety Engineering includes Safety Analysis.



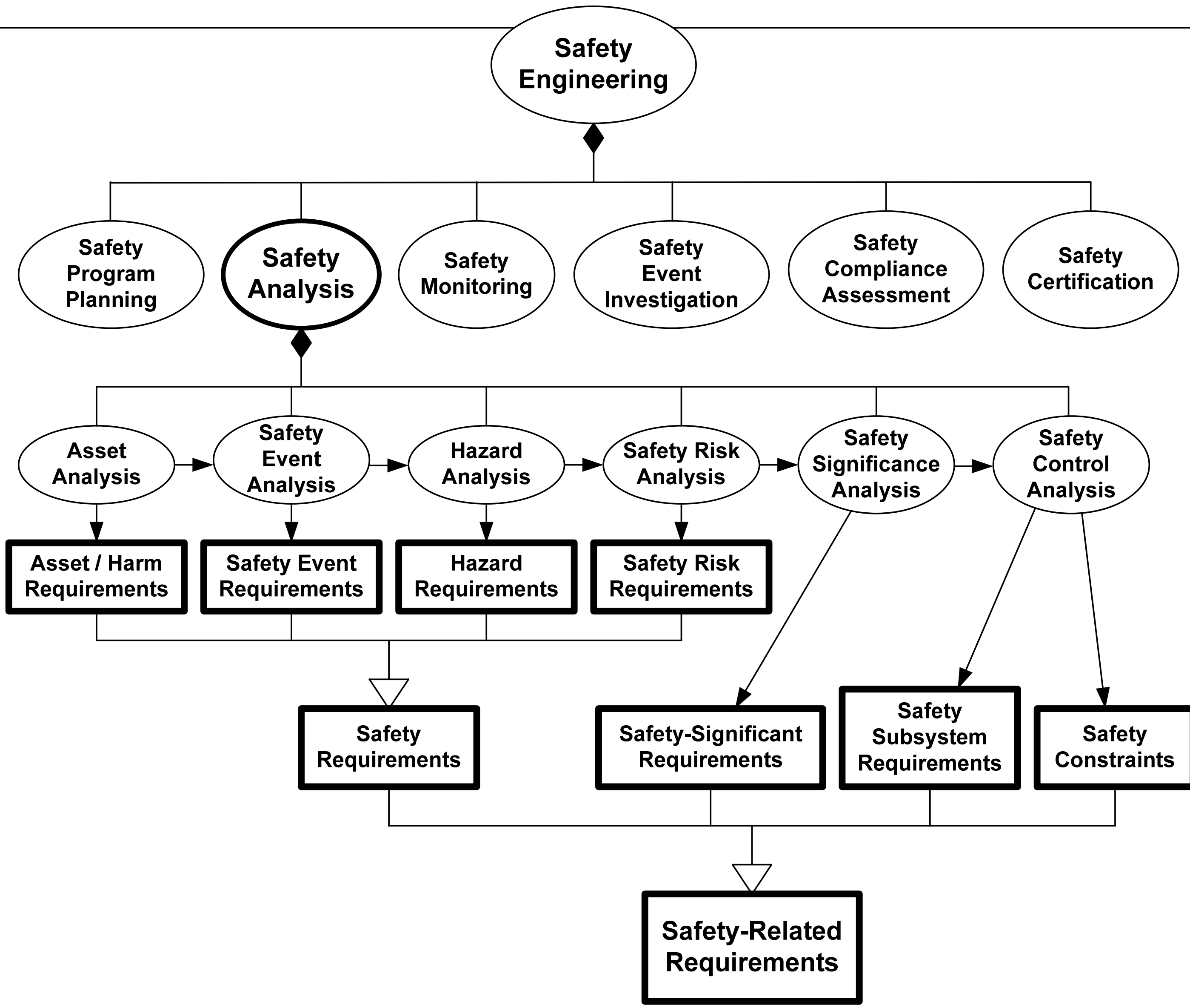
Safety & Requirements Engineering Interface



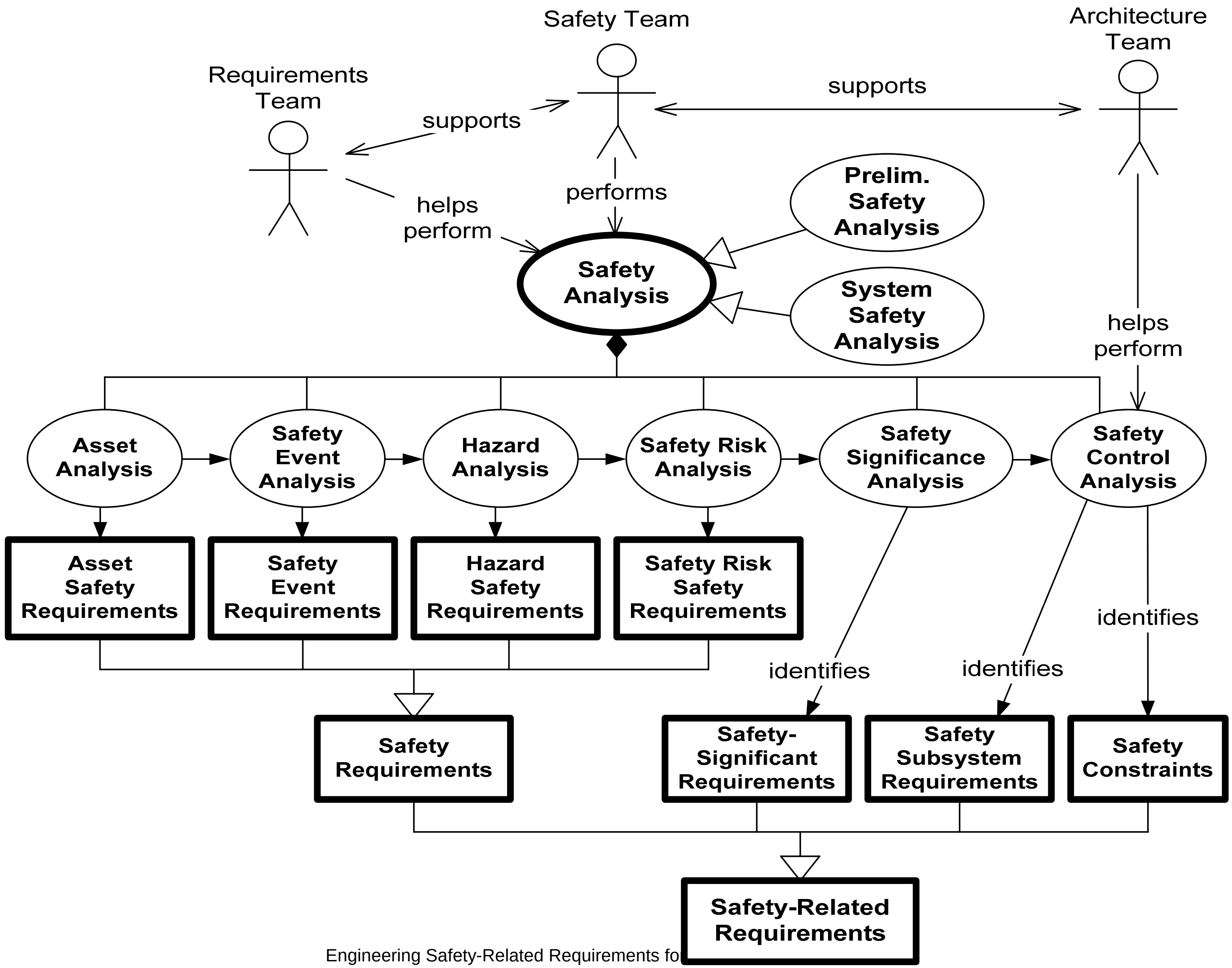
Safety Program Planning



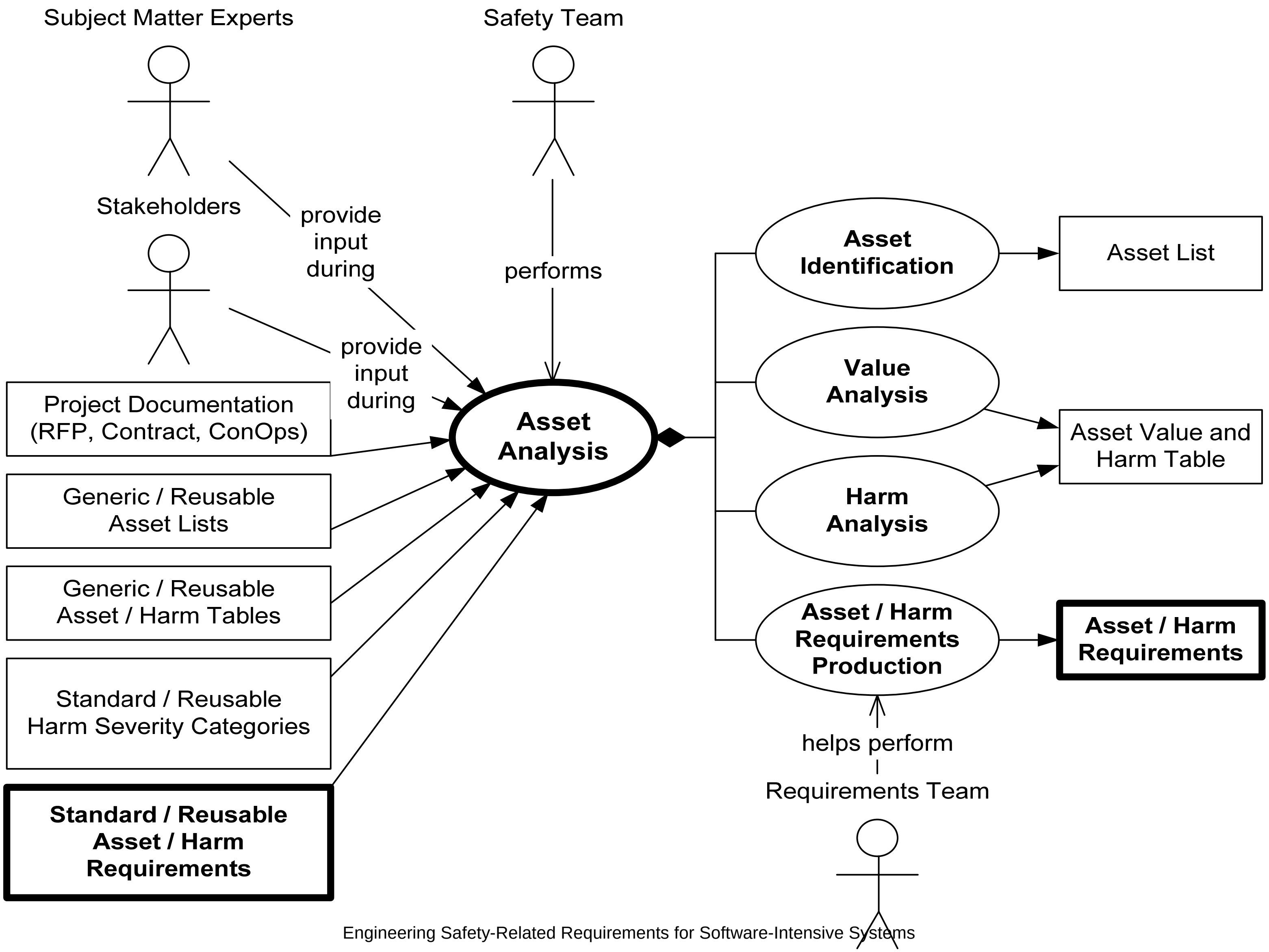
Safety Analysis Yields Safety-Related Rqmts



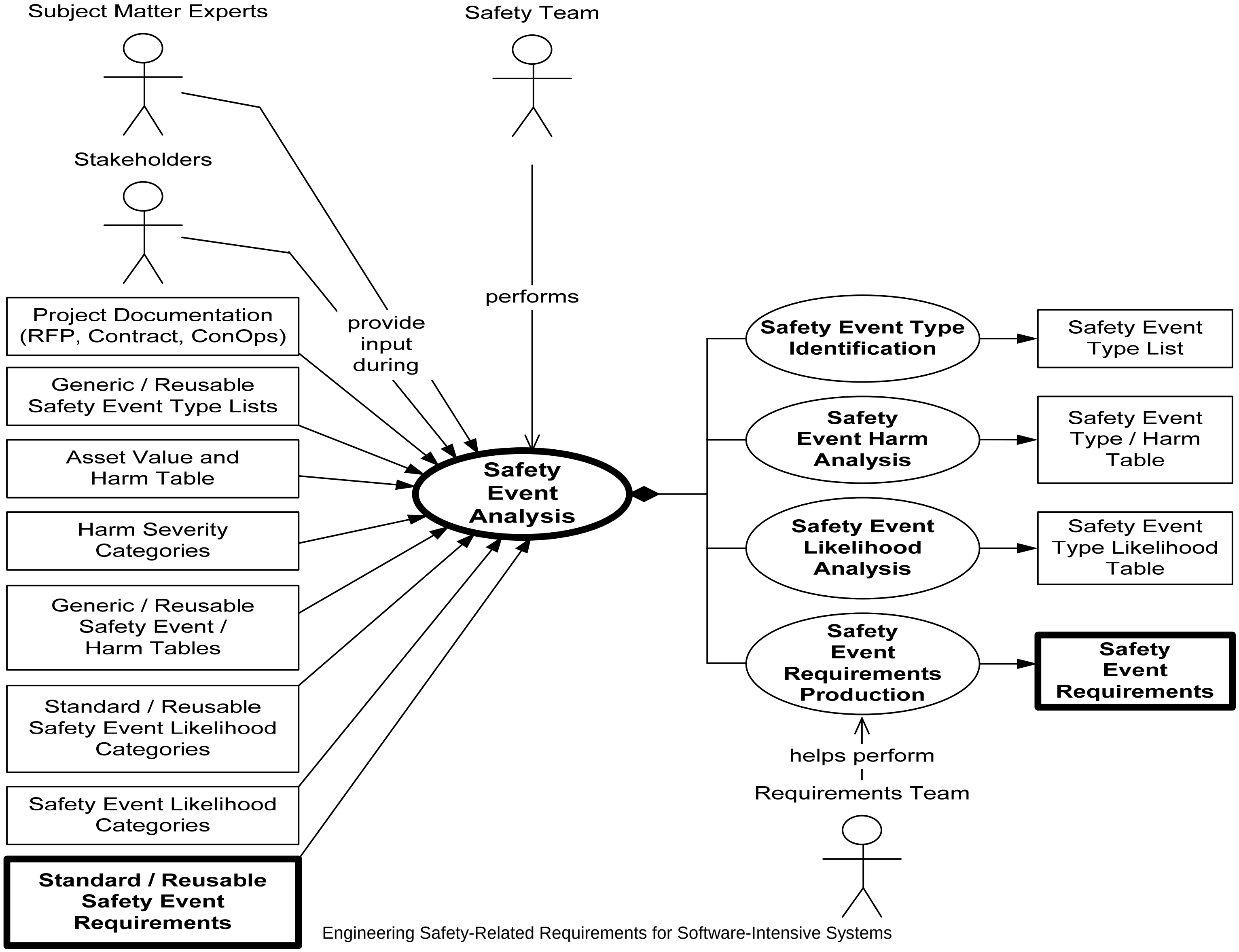
Safety Analysis Requires Collaboration



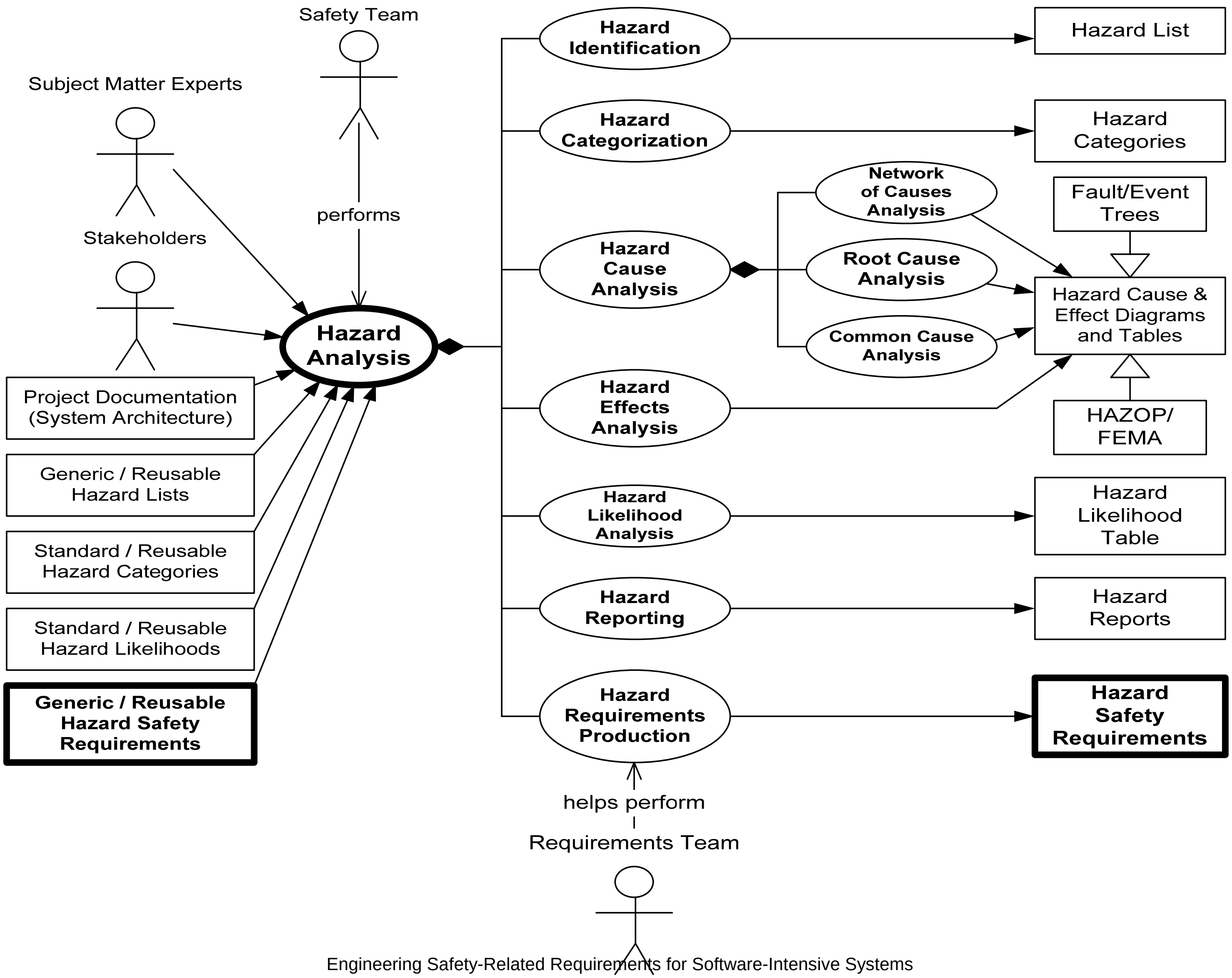
Asset Analysis



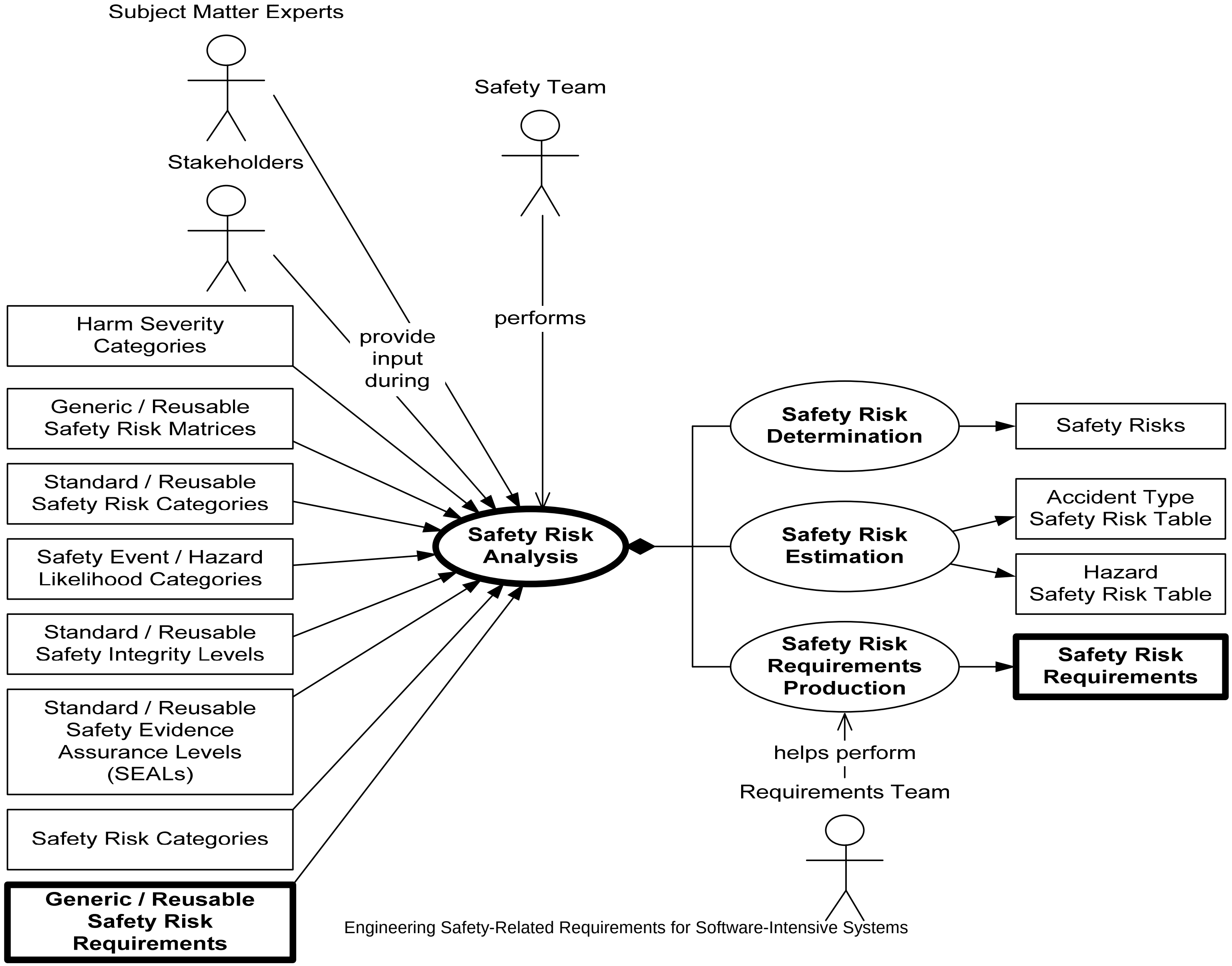
Safety Event Analysis



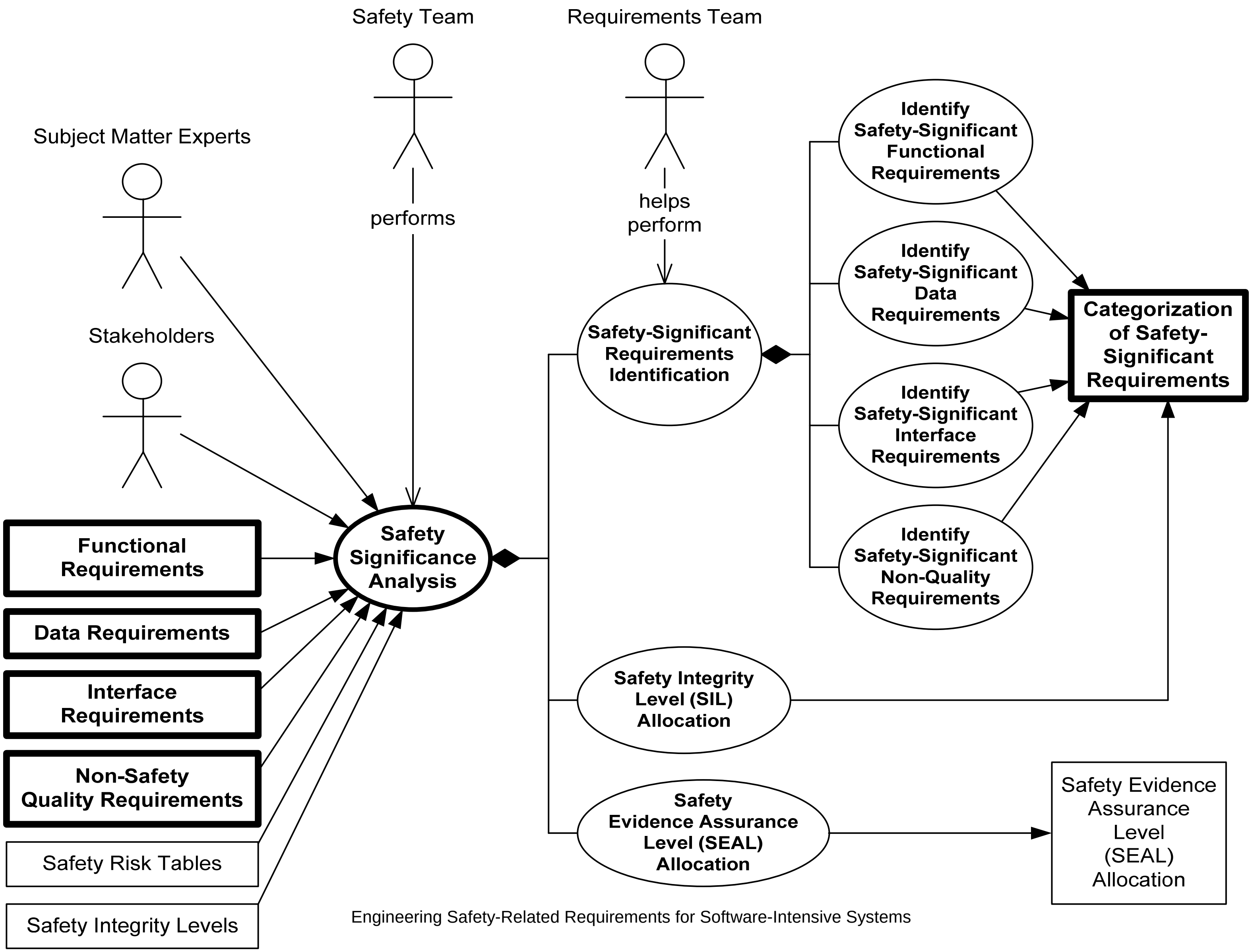
Hazard Analysis



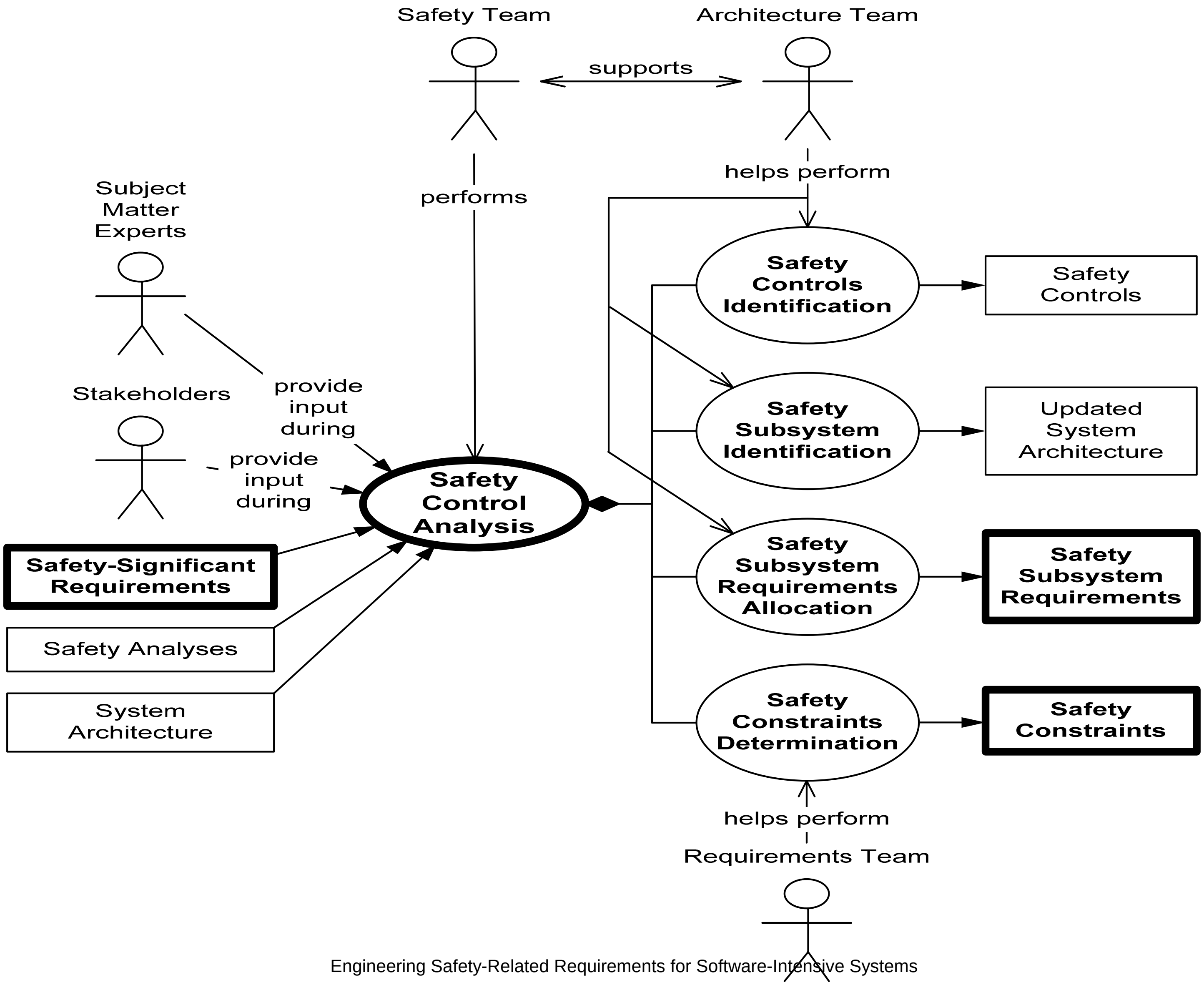
Safety Risk Analysis



Safety-Significance Analysis



Safety Control Analysis



Conclusion

- Engineering safety-significant requirements requires *appropriate*:
  - Concepts
  - Methods
  - Techniques
  - Tools
  - Expertise
- These must come from *both:*
  - Requirements Engineering
  - Safety Engineering

Conclusion (2)

- There are four types of safety-related requirements:
  - Safety Requirements
  - Safety-Significant Requirements
  - Safety Subsystem Requirements
  - Safety Constraints
- They have different forms (structures, contents).
- They need to be identified, analyzed, and specified differently.

Conclusion (3)

- The requirements engineering and safety engineering processes need to be:
  - Properly interwoven.
  - Consistent with each other.
  - Performed collaboratively and in parallel (i.e., overlapping in time).

Final Thoughts

- Full day tutorial with examples and student exercises to be given at ICSE'06 in Shanghai (22 May 2006).
- Look for my upcoming book by the same title.
- For more information, check out this repository of over 1,100 free open-source reusable method components including many on safety at www.opfro.org.